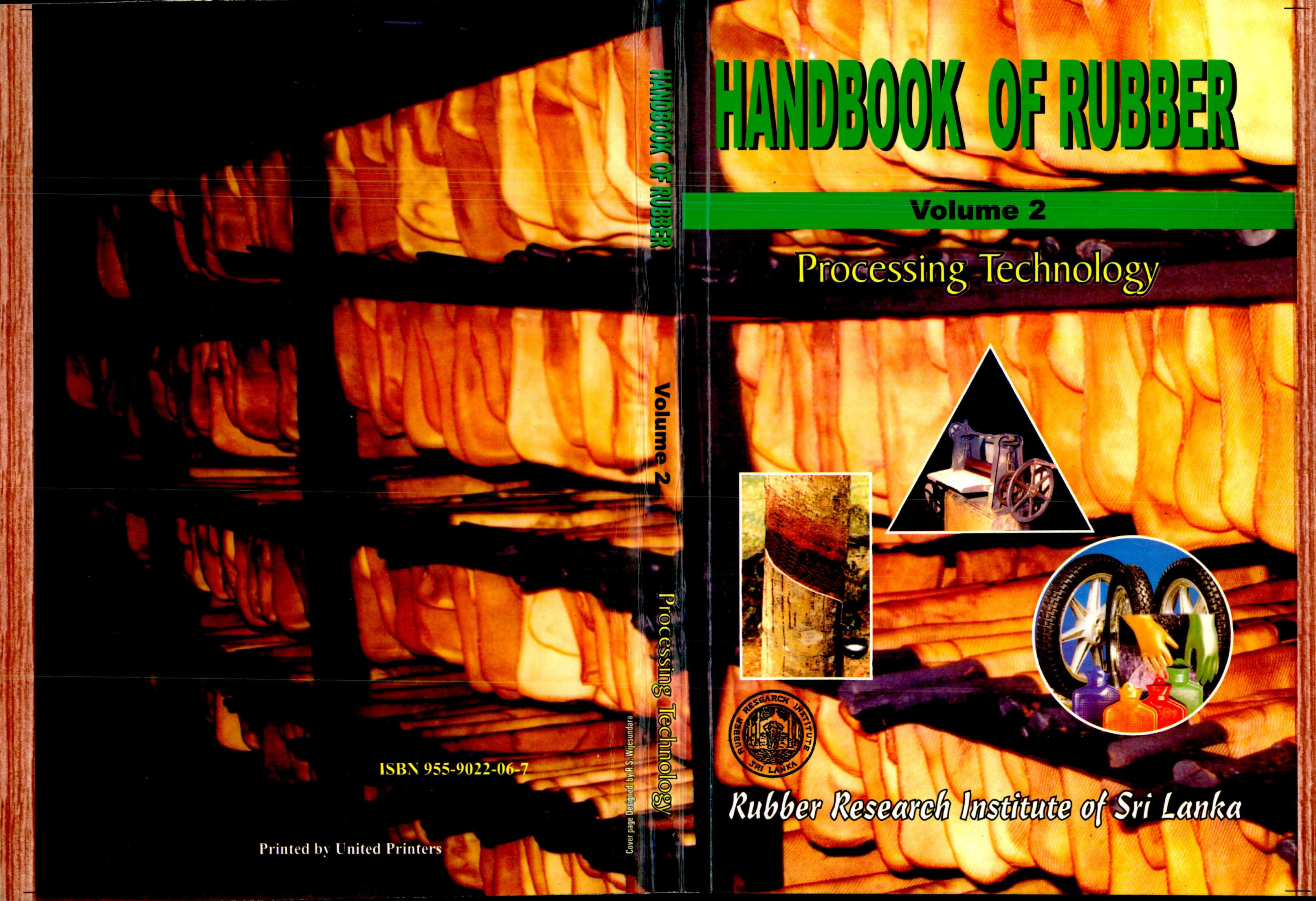

HANDBOOK OF RUBBER

Volume 2

Processing Technology

Rubber Research Institute of Sri Lanka

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Processing Technology

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Correction Slip

Page	Place	Details of error	Change to
iv	1st para, line 3	Castilla	Castilloa
iv	4th para 2nd line	for	as
iv	4th para, 6th line	Shreaded	Shreded
5	Sec 5.11, Line 11	29 parts	15 parts
6	2nd para, 2nd line	Metrolc	Metrolac
21	Colour chart	Colour reaction on blue	Insufficient acid
46	Section 5.2	(Plate 3.2b)	Should be deleted
54	Section 7.5	Nitrogen <0.06	Should be <0.6
62	2 lines from the bottom	COM	Cost of manufacture
115	TMTD molecular weight	178	240
124	1st & 2nd line	Repetition	Should be deleted
127	2.4.2 2nd para, last line	product	mould
138	7th line	P	part
152	2.1, last line of last para	type	authentic
175	Introduction 2nd para 7th line	Sediment	Phase
Annex 1	Metrolac chart Line 13	Readings incorrect	All readings should divided by 2

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Edited by
L.M.K. Tillekeratne
Director

A. Nugawela
Deputy Director-Research (Biology)

W.M.G. Seneviratne
Deputy Director-Research (Technology)

Rubber Research Institute of Sri Lanka
Dartonfield
Agalawatta
Sri Lanka

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Contents

Introduction

The natural rubber plant was first introduced to the South East Asia from its native South America when seeds sent by Henry Wickham were germinated in the Kew Gardens in UK and the infant seedlings were planted at Henarathgoda Garden in Colombo district in Sri Lanka in 1876. Hence, Colombo is known as the cradle of rubber plantation in the world. The commercial planting of rubber in Sri Lanka was started in 1883.

In order to develop technology demanded by the growers a committee consisting of members of British plantation interests in this country was formed in 1909. This committee engaged a Chemist to study the coagulation of rubber thereby initiating research on rubber in 1909 in Sri Lanka. Hence, RRI Sri Lanka is the oldest rubber research institute in the world.

Rubber product manufacture in Sri Lanka began in 1936 with the establishment of a tyre retreading facility. However, it is only during 1980's that the rubber products manufacturing sector began to expand. This could be attributed to the liberalization of the trade and investment in 1977. In order to promote this sector, rubber products manufacturing sector was recognised as a thrust industry by the government of Sri Lanka and is recognised as the target industry in the master plan for industrialisation and investment promotion prepared by the ministry of Industrial Development. Hence this sector is qualified for a package of special incentives offered to BOI companies.

Today Sri Lanka is renowned to be the worlds' largest producer of industrial solid tyres; while in the examination and surgical gloves sector too Sri Lanka is the 4th largest in the world. Apart from that moulded and extruded products such as solid and pneumatic tyres, tubes, rubber belts, wide variety of automotive components, agricultural and other hoses, industrial flooring and mats and shoe soles are the major items produced by the Sri Lankan industry. Surgical, household, agricultural and examination gloves, balloons, Halloween masks, foam rubber toys are among the latex based product industries of the country. Latex based product industry attributes to around 35% of the local rubber consumption.

As in the past, the aim to enhance the rubber industry by continuous development of the productivity of rubber plantation to cater to the fast growing needs of the value added rubber products industry. For this purpose plans are underway to extend the rubber plantations to non traditional areas in the country.

Upgrading technology on raw rubber processing, promoting the premium grades of latex crepes manufactured exclusively by Sri Lanka for the food, pharmaceutical and infant toy industry to gain highest price payable from the correct end-users, developing the rubber product manufacturing industry by eliminating problems such as protein allergy, sulphur blooming and environmental pollution are the other aims of this institute which is the only institute of this kind in the country. In order to achieve these aspirations research is carried out in the areas of agronomy, processing and technology in cost effective and environment friendly manner.

L.M.K. Tillekeratne
Director

Forward

Research and development activities are mandatory for the development of any industry. In the light of this situation to develop technology demanded by the growers a committee consisting of members of British plantation interests in this country was formed in 1909. Therefore, the origin of research on rubber in Sri Lanka goes back to that year. The committee initially engaged a chemist to study the coagulation of rubber. This activity was later expanded to form the Rubber Research Scheme in 1913, with Government providing 60% of the required funds and the balance coming from private subscribers. In 1914, the Rubber Growers' Association, based in London, inaugurated the Rubber Growers' (Ceylon) Research Fund to provide further research facilities. The Ceylon Rubber Research Scheme and the Rubber Growers' (Ceylon) Research Fund amalgamated their work in 1920 and the Government continued to provide 60% of the funds.

In January 1926 the Scheme leased 65 acres of land at Nivitigalakele, Matugama in the Kalutara District to further extend the Rubber Research Scheme activities on planting and testing of new clones. Later the Smallholdings Advisory Department was developed and was ultimately transferred to Colombo. This Department, apart from providing advisory services, helped smallholders by providing high-class planting material at subsidised rates.

With the development of the industry the necessity to disseminate the technology developed to the growers was felt. Therefore, the Rubber Research Ordinance No.10 of 1930 incorporating the Ceylon Rubber Research Scheme became operative. This ordinance provided provision to collect a cess of one-eighth cent per pound of rubber exported from the country and to utilize the funds for research work on rubber administered by a Board of Management.

The 178-acre estate known as Dartonfield in the Kalutara District was purchased in 1933 and was converted into a Research Station with factories, laboratories and bungalows. The experiments laid down at the Research Station created great interest among the rubber planters and the out-come of such studies was disseminated through publications, visits to estates and meetings of District Planters' Associations.

In 1942, a lease of 1,000 acres of land at Hedigalla in the Kalutara District was secured for the purpose of expansion of existing facilities for research. The Rubber Research Scheme was officially styled "Rubber Research Institute" in 1951 by the provisions of the Rubber Research (Amendment) Act. No.30 of 1951. The work of the whole Institute was greatly expanded in 1953 with the introduction of the subsidized rubber replanting scheme. The original act of parliament was again amended by the Rubber Research (Amendment) Act No. 39 of 1987.

As in the past this Institute, the oldest of its kind in the world, aims to enhance the performance of the rubber industry by continuous development and upgrading of technology on raw rubber processing, rubber products manufacture and agro-management taking into consideration the prevailing circumstances and also environmental issues. In order to fulfill these aspirations research and extension activities are carried out on all aspects of rubber cultivation and processing, in a cost-effective manner.

Among the different methods adopted by the institute to disseminate the technology developed to the end users publications play an important role. Effective transfer of latest technology developed by the institute to the growers and industrialists is vital with the current level of competition in the global rubber industry. `A Handbook of

Rubber Culture and Processing' published in 1983 included the recommendation on both Agronomy and Processing. In 2000 'Handbook of Rubber, Volume 1. Agronomy' was published updating the institute policies on agromanagement of rubber plantations. This publication 'Handbook of Rubber Volume 2, Processing' gives the latest institute recommendations on raw rubber processing and product manufacture.

A. Nugawela,
Deputy Director Research (Biology)

Preface

History of Natural Rubber

Christoper Columbus in his expedition tour to America in 1493 has found the natives of Haiti playing with solid balls which bounced up into the air. The rubber used to make these balls was from Maxican rubber yielding tree, Castilla Elastica. By this time, people in Maxico and Guatemala had already discovered the tapping of latex from these trees which were made use of manufacturing water proofing garments and footwear at that time.

When Columbus sailed back from the West Indies with the rubber balls to Spain in 1496, it was the first known presence of natural rubber in Europe and it was said of them that there was 'nothing comparable in the world to the way that the balls bounced'. Its first use in latex form was the discovery, by the Spaniards, of its ability to waterproof fabrics. However, since 1615 there was no means of stabilizing the latex, a thriving fabric proofing industry sprang up in Mexico with the latex coated fabric being exported.

In 1818 Charles Macintosh, a British Scientist also discovered water – proofing. While seeking ways to exploit the waste products of the new coal gasification process, he found that coal tar naptha was a good solvent for rubber. This rubber solution was then used as a waterproofing layer between two fabrics. Hence the "Machintosh'.

Close on Macintosh's new process came Thomas Hancock;'s discovery of mastication in 1820. Hancock was using thin rings of rubber for elastic fastenings for gloves, shoes and stockings. This industry generated fresh cut edges of waste. Hancock developed a wooden masticator to shred the rubber. This was made from a cylinder of wood studded with teeth surrounded by a wooden frame also with teeth. He then found that these shreaded rubber could be turned into a homogeneous product by applying heat and pressure. Later models were properly engineered and Hancock used his masticated rubber to supply Macintosh's factory. He kept his process secret, but was forced to patent it in 1837.

In this post – mastication/prevulcanization period, the rubber industry grew in Great Britain and a range of applications for rubber were developed covering the whole spectra of items from cushions and mattresses through bellows, hoses, (for beer engineers and fire-engines) to shoes and even early tyres. However, whilst rubber products were suitable in Britain with its relatively mild and wet climate, this was not so in the United States. Here excessive high temperatures or cold made Macintoshes and related products either sticky or rigid, resulting in loss of confidence in the US rubber industry and many factories were closed down. This failure of rubber to meet these temperature changes made Charles Goodyear seek modifications to it to avoid this defect. He tried a variety of chemicals and processes including magnesia, boiling in lime, bronze powder and nitric acid. It was actually Nathaniel Hayward who first introduced Goodyear to sulphur in 1838 on, rather than in, the rubber. However, Goodyear fell upon hard times both financially and domestically, so it was not until 1841 that he accidentally over –heated a mixture of rubber, sulphur and white lead, which led to the discovery of vulcanization, and a rubber which did not harden in winter and soften in the summer.

Goodyear patented his invention on December 6th, 1842. Hancock, to whom the discovery of vulcanization is also often ascribed, came into the picture via William Brockendon (who is thought to have coined the name 'vulcanization'). Public opinion in the US was still hostile to rubber, so Goodyear entrusted his idea to a Stephen Moulton who was returning to England to take his improved rubber to the now prospering Macintosh Company. Somehow Willaim Brockendon obtained samples of Goodyear's rubber and passed them to Hancock, who deduced from the bloom that sulphur was present. Thomas Hancock then discovered that strips of rubber immersed in molten sulphur changed character, and patented the process in November 1843, only a few weeks before Goodyear's belated English patent.

The British rubber industry thus grew still further with the advent of vulcanization. This demand for rubber had grown quite significantly following John Boyd Dunlop's (a Scottish veterinary surgeon) invention of the pneumatic tyre in 1888. Whilst steam vehicles were too heavy for those, the early petrol cars were not, and the Michelin Brothers completed the 1895 Paris – Bordeaux car race on a vehicle fitted with pneumatic tyres. In the early days of motoring, tyres could cost $100 and cover only 750 kilometres. By the 1920s the cost was down to $30 and expected mileage raised to 21 000 kilometres. Aircraft tyres were first marketed around 1910, but the first pneumatic truck tyres did not appear until 1917 almost 30 years after Dunlop's invention.

From then on, there was feverish activity in seeking new uses for rubber along with producing modified forms. Rubber in roads came about immediately after the war in 1947, following developments by British Rubber Producers Research Association (BRPRA), the use of rubber in roads as rubberized bitumen gave better grip, a one – third improvement in the life of the surface.

New material substitutes for natural rubber came thick and fast in the 1950s. There was Rubbone in 1952, the first form of liquid rubber that was widely used for prototype components, printers' rollers and textile machine parts after vulcanization. BRPRA also developed positively charged NR latex known as "Positex" which when applied on wool gave a waterproofing effect with improved wear properties and the elimination of 'balling up'. In 1954, Methyl Methacrylate grafted (MG) rubber was developed and MG '30' '40' and '49' became available based on the methyl methacrylate content. They are commonly used as adhesives.

Then there were new uses that were developed. Perhaps most important of these was the use of rubber – metal laminated bearings for bridges. The first occasion these were installed – in place of the old roller bearings – was the Pelham Bridges outside Lincoln in 1957. Since that time all bridges around the world have rubber bearings to accommodate bridge deck movement, and the concept spawned the base-isolation of whole buildings against ground – borne vibration. In 1965 when Albany Court was built. It became the first building in the world constructed on rubber – metal laminated bearings, to isolate it from the St. Jones wood underground station built below it.

The final development of base – isolation has been the design of rubber –metal laminated bearings to protect buildings against earthquakes and this is likely to represent a substantial new use of rubber in the 21st century.

Another development in the late 1960s was the discovery that oil –extended natural rubber (OENR) had potential use in winter tyre treads which provided good ice and snow traction properties, better rolling resistance than synthetic rubber treaded tyre and has also been evaluated in all season tyres which were originally made out of synthetic rubbers.

The 1970s and 1980s have seen new rubbers derived from natural rubber and further uses, all of which are known to readers today. In late 1970s Deprotinized Natural rubber was introduced to give oil resistance, damping and low gas permeability, while Theremoplastic natural rubber (TPNR) joined the recycling and no – reject club.

Work has continued to keep NR in the tyre industry where some 70% of rubber is consumed. NR is mainly used in the truck tyres, air craft tyres and off the road tyres. NR based compounds have now been developed which can give equivalent wear performance to synthetic rubber treads (SBR/BR) and in addition have lower rolling resistance and hence give better fuel economy. Finally the NR industry has learnt to live with SR. For majority of applications, blends tend to be used.

And so to the future, NR production continues to climb, with 5.9 million tonnes produced in 1995. With a total world rubber consumption of 15.2 million tonnes, this represents 39% of the market. In the year 2002 world NR production has climbed to 7.1 million tonnes while the Synthetic rubber production was 10.8 million tonnes. The low rolling resistance of NR, combined with high tack and low heat buildup, make it an ideal polymer for the tyre industry. The trend to manufacturing in the Far East, where 50% of NR is now consumed, has an ideal-bred bias to use home grown NR, whilst the latex industry also continues to grow. These developments envisage a bright future for NR.

NR continues to save lives in the medical field as well. Surgeons gloves and examination gloves are now universally used to protect hospital workers, dentists and others in the medical field against AIDS. The market has risen dramatically since 1988, and for the most part consumers cannot imagine a better material for feel and grip.

All the predictions for cars of the future, envisage the use of rubber in tyres, albeit their profile may change and their weight decrease. This together with tomorrow's world space shuttles and other aircraft landing on NR tyres, should see a bright future for the NR industry.

Rubber industry in Sri Lanka - at a glance

Natural rubber produced in Sri Lanka is a valuable resource for the rubber industry, as well as for foreign exchange earning through exports. The rubber industry in Sri Lanka is one of the five largest GVA sub sectors and contributed 6.5% of the total manufacturing GVA in 1995, being a typical resource-based industry backed by high quality NR produced in the country. In the year 2001, export of rubber products earned a foreign exchange revenue equivalent to Rs.17 billion while export of raw rubber accounted for Rs.2.5 billion.

It is reported that in 2001, the country produced 86.2 thousand tonnes of NR, of which 54 thousand tonnes were consumed by the rubber manufacturing industries locally which figure reflects a significant growth in the industry over the two decades as it was only 14 tonnes of rubber consumed in the early 1980s.

Rubber product manufacturing began in Sri Lanka way back in 1936 with the establishment of a tyre retreading facility. However, it was only during the 1980s that the manufacturing sector began to expand. Expansion was slow at first but gathered momentum in the early 1990s. The successful growth of the industry can be partly attributed to the liberalization of the trade and investment in Sri Lanka which began in 1977. Very attractive incentives have been on offer for potential investors in export oriented projects. In 1997, in order to promote the sector, the rubber based manufacturing sector was named as a " Thrust Industry" by the government and thereby new investments in this sector qualified for special incentives. Most of the large scale industries are either direct foreign investments or joint ventures with local partners.

The rubber industry in Sri Lanka has the potential to be one of the world leading rubber product manufacturing countries due to it's production of top quality grade of NR with a very low level of proteins and production of high quality RSS as raw materials at relatively low processing cost. Wide variety of rubber products are manufactured by the rubber manufacturing sector in Sri Lanka.

Moulded and extruded products such as solid and pneumatic tyres, tubes, rubber belts, wide variety of automotive components, agricultural and other hoses, industrial floorings, mats and shoe soles are major items produced by the Sri Lankan industry. Sri Lanka is renowned to be the world's largest supplier of industrial solid tyres.

Surgical, household, agricultural and examination gloves, balloons, halloween masks and rubber toys are among the major products manufactured by the Latex product industries in Sri Lanka. Latex product industry has expanded significantly over the last decade and presently it attributes to around 35% of the local consumption of NR.

W.M.G. Seneviratne
Deputy Director Research (Technology)

Acknowledgements

"A Handbook of Rubber Culture and Processing" edited by Dr O.S. Peries and Mr D.M. Fernando (1983) is updated in this book in the light of modern developments. The 1983 Handbook provided the model on which this version is based, for which we are most grateful to its editors and writers. The present version includes several new chapters to accommodate some recent innovations.

Prof. M.D. Dassanayake, consultant editor perfected each chapter with dedication. We owe a debt of gratitude for the invaluable contribution made by him. Also, assistance given by Dr (Mrs) L. Sivagurunathan and Mr S.W. Karunaratne in editing some chapters is appreciated.

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Finally, it is a pleasure to thank all contributors who so readily wrote on their own specialities. We are thankful to United Printers, Moratuwa for excellent printing.

L.M.K. Tillekeratne
A. Nugawela
W.M.G. Seneviratne
Editors.

Chapter 1

Latex collection*

P.H. Sarath Kumara

1. INTRODUCTION

Fresh latex from the rubber tree is a rather thixotropic neutral milky fluid of density around 0.98 g/cm^3. The rubber hydrocarbon, chemically called cis 1,4 polyisoprene, is in colloidal suspension in water as molecular aggregates of 0.5 to 1.0 micron (1/1000 of a mm) diameter. In addition, latex contains proteinaceous and nitrogenous substances, carbohydrates, lipids, mineral salts, carotenoids, resins and enzymes.

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* Adapted from "A Handbook of Rubber Culture and Processing", 1983

2. COMPOSITION OF LATEX

Being a natural product, the composition of Natural Rubber (NR) latex varies depending on many factors such as clone, season, soil conditions, tapping method and frequency, the age of the tree, etc. The typical composition is as follows:

Component	% by weight of latex
Dry rubber	30 – 35
Proteinaceous substances	1 – 1.5
Lipids	1 – 2.5
Sugar	1
Inorganic ions	1
Water	60 – 65

It is believed that a rubber particle in fresh NR latex comprises a sphere of mainly rubber hydrocarbon, surrounded by two layers, the inner of phospholipids and the outer of proteins (Fig. 1.1).

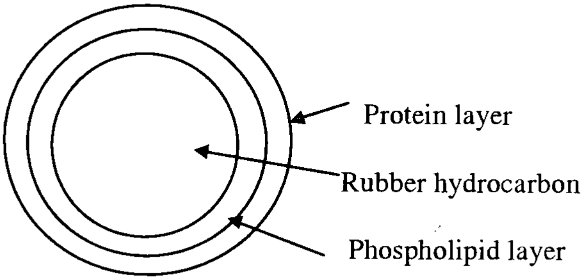

Fig 1.1 The structure of a natural rubber particle

In addition to rubber particles, fresh latex also contains two other types of particles: bright yellow particles known as Frey-Wyssling particles which cause yellow discoloration of rubber and lutoid particles much larger than latex particles which contain carotenoids, acids, mineral salts, proteins and even rubber hydrocarbons. When fresh latex is diluted, these lutoid particles absorb water and become larger in size eventually bursting and releasing the contents into the serum. The lutoids and their residuals coagulate more readily than rubber particles because of the acidic substances present in the particle. This fact is made use of in the fractionation process in crepe rubber manufacture.

3. UTENSILS FOR LATEX COLLECTION

3.1 Spouts

Latex is channeled to the collecting vessel by means of spouts. Various types of spouts are in use. The scrap should be removed daily to keep the spouts clean Spouts are usually made of galvanized iron and are about 5 cm long.

3.2 Latex cups

Coconut shells are mostly used for collecting latex in Sri Lanka due to the low cost and their ready availability. They should be replaced by clean shells after they have become encrusted round the edges and outside with sticky scrap. Dirty cups are a source of infection, leading to precoagulation in the field and to fermentation and bubble formation in the factory.

Cups should not be allowed to lie on the ground, as latex is bound to become contaminated with soil. Some spouts have hooks by which the cups could be hung when not in use. Cups can also be inverted on pegs placed in the ground close to each tree or hung on cup hangers.

Cups made out of plastic could also be used for collection of latex. Use of these cups may help to reduce the percentage of scrap, as it is easier to remove latex from these cups; these plastic cups are relatively cleaner than coconut shells.

3.3 Buckets

The collecting buckets most commonly used are of galvanized iron. Buckets should be adequately washed after use and they should be inspected before the tappers leave the factory. There is no difficulty in cleaning utensils used for collecting latex if this is done immediately after use. It is only when the latex is allowed to dry, that it becomes tacky and difficult to remove. Unclean buckets are a source of bacteria which by contaminating the latex increase the tendency for precoagulation and also affect the quality of the rubber manufactured.

Careful attention should also be paid to the "kottu" or the small receptacle tappers use to facilitate the collection of latex.

When the tapping cut on trees comes within 30 cm from the ground, there is likely to be an increase in the dirt content of latex. The dirt is splashed on to the trunk or into the cup during rain and is then carried through to the factory with the latex.

4. TIME OF COLLECTION OF LATEX

Latex should be collected as soon as possible after the flow has ceased, which may be 3 to 4 hours after the first tree is tapped. If signs of precoagulation are observed in latex, it is necessary to use an anticoagulant in the field. This fact must be borne in mind when divisional weighing sheds are built.

The latex is poured from the cup into the collecting bucket and as much as possible is removed from the cup with the thumb. The use of lumps of rubber for cleaning out the cups should not be allowed, nor is it desirable to allow the cups to be rinsed out with water. The tappers should not be allowed to leave the buckets standing in the sun as the heat increases the tendency for fermentation and precoagulation of latex. The rise in temperature of latex due to warming also appreciates the metrolac reading (see 7.3.1 and Fig. 1.3).

5. PRESERVATION OF LATEX

Latex from young trees and from trees of certain clones shows a marked tendency for precoagulation prior to arrival at the factory. This is indicated by visible clots in the collecting cup itself, clots in latex, coagulation during transportation and fermentation bubbles in the coagulum. Precoagulation mainly occurs in latex due to acid development by bacteria interacting with various non-rubber substituents. In the presence of bacteria non rubber such as certain proteins, lipids and sugar are converted to acids. Low molecular weight volatile fatty acids such as acetic and formic acid generated by bacterial action on sugar results in precoagulation while formation of acids with the digestion of proteins and lipids helps stabilization of latex.

Most predominantly a sugary substance present in latex namely quebrachitol is digested by means of bacteria in the presence of oxygen to form acetic and formic acid as follows;

$$\text{Quebrachitol + Oxygen} \xrightarrow{\textit{Bacteria}} \text{Acetic acid + Formic acid}$$

Tendency for precoagulation is often particularly noticeable immediately after resting for wintering, tapping of high cuts and in wet weather.

Latex to be used for manufacture of sheet or crepe rubber should be preserved with chemicals to prevent precoagulation until it reaches the factory for further processing. These chemicals used as short-term preservatives are known as anticoagulants. Preferred anticoagulants are sodium sulphite, ammonia and sodium carbonate. However, sodium sulphite is the most commonly used anticoagulant in Sri Lanka.

A limited number of preliminary trials is usually desirable prior to the large-scale use of latex anticoagulants. The objective of these trials is to ascertain whether the anticoagulant chosen is suitable and to obtain some information concerning the amount of anticoagulant to be used at various stages, i.e., (a) in the bucket and (b) at the collection centre, as well as to train the estates' staff and some of the tappers in the procedures involved. Further, the quantity of anticoagulant to be used on an estate may not be the same throughout, because of variation in weather and clones.

Latex used for manufacture of concentrated latex should be preserved with long-term preservatives. The most popular long-term preservatives are ammonia and a combination of ammonia with a secondary preservative such as TMTD/ZnO.

5.1 Preparation and dosage of preservatives

Ammonia is diluted to the required concentration as described in 5.1.1 for preparing the stock solution before addition to latex. These solutions could be kept for an appreciable period of time in storage if containers are kept tightly closed. However, stock solutions of sodium sulphite are not stable and should be made just prior to use, as sodium sulphite in solution loses its strength very rapidly.

The stock solutions of ammonia, sodium sulphite and washing soda are prepared and used as follows:

5.1.1 Ammonia

Ammonia is available in steel cylinders containing about 68 kg liquified ammonia gas under pressure. The stock solution to be used as an anti-coagulant is prepared by bubbling 1 kg of ammonia gas carefully and slowly into 100 litres of water giving a 1% solution. If ammonia is used as a long-term preservative, the stock solution is prepared by bubbling 10 kg of ammonia into 100 litres of water to obtain a 10% solution. Liquid ammonia can be obtained at concentrations ranging from 25 to 30% by weight. The bottle of concentrated ammonia intended to be opened the following day should be left to cool, immersed in a bucket of water the previous night, and the bottle should be opened with care and the operator should wear goggles. The stock solution is prepared by diluting 1 part and 10 parts of the liquid ammonia solution with approximately 24 or 29 parts of water to obtain a 1% and a 10% solution respectively. Aluminium vessels are not suitable for the storage of strong ammonia solution.

Ammonia as an anti-coagulant is added to field latex at 0.01 - 0.05% on latex. The addition of 100 - 500 ml of a 1% solution to 10 litres of latex gives this dosage. Ammonia is considered suitable as an anti-coagulant in the manufacture of sheet rubber, but not in the manufacture of crepe rubber as the resulting crepe may discolour.

Field latex collected for High Ammonia preserved concentrated latex manufacture should contain an ammonia content of 0.4%. Addition of 4 litres of a 10% solution to 100 litres of latex gives this concentration approximately. This concentration can be reduced to 0.2% by adding half the above dosage with a secondary preservative such as TMTD/ZnO added as a 25% dispersion. The dosage of TMTD/ZnO is 0.025% on latex. Addition of 100 g from the dispersion mixture into 100 litres of latex gives this concentration. The collecting vessels should be kept closed airtight to prevent the escape of ammonia from latex. It is recommended that latex be delivered to the centrifuging factory as early as possible. Failure to do so will increase the risk of Volatile Fatty Acid (VFA) formation in latex. Latex with high VFA No. is not suitable for concentration.

5.1.2 Sodium sulphite

The stock solution of 3.3% is made by dissolving 1 kg of the anhydrous chemical in 30 litres of water. The addition of 150 ml of this solution to every 10 litres of latex should give a sodium sulphite content of approximately 0.05%. The stock solution should be made up just prior to use. Sodium sulphite may not be effective if the tendency to precoagulation is marked. The recommended dosage of sodium sulphite is 0.05 - 0.15% on latex. There is no necessity to increase the dosage beyond the recommended levels, if correct hygienic practices are adhered to. Excess sodium sulphite retards the drying of sheet and crepe and leaves the surface of sheets tacky (or glossy) due to moisture absorption.

Sodium sulphite, in addition to being an anticoagulant, prevents enzymatic discolouration of the latex resulting from (a) increased tapping intensities (b) tapping after the wintering period (c) new tapping cuts.

5.1.3 Washing soda

The stock solution is made by dissolving 1 kg of the powder in 60 litres of water. The addition of 300 ml of this solution to every 20 litres of latex gives a sodium carbonate content of approximately 0.025%. This anticoagulant may be suitable for smallholders due to low cost but it is believed that there is a risk of bubble formation, e.g. in RSS manufacture.

The approximate quantities of anticoagulant used as a percentage of the weight of latex are given in Table 1.1. However, this material is not used commercially by the smallholder sector or estates.

5.2 Effect of anticoagulants on rubber manufacture

Excessive proportions of anticoagulants should not be employed as it may cause difficulties in removing the fraction and the consumption of acid for coagulation will consequently increase.

5.2.1 Sheet rubber manufacture

The use of washing soda or sodium carbonate as the anticoagulant can give rise to bubble formation in sheets manufactured due to chemical action of acid on the anticoagulant during coagulation. If bubble formation (pin head bubbles) in sheet is due to bacterial action, then sodium sulphite is preferable to washing soda as the anticoagulant. If sodium sulphite is added in the field or in the transportation tank as the anticoagulant, then it is not necessary to use any sodium bisulphite in the factory as excess of sodium sulphite or bisulphite retards the drying of sheets and leaves the surface tacky. Ammonia is the best anticoagulant for sheet manufacture.

5.2.2 Crepe rubber manufacture

Sodium sulphite is the best anticoagulant for crepe manufacture and if used in the field or in the transportation tank, the amount of sodium bisulphite used in the factory can be reduced accordingly. The use of ammonia is not recommended as it may cause discolouration in the resultant crepe.

Table 1.1. Quantities of anticoagulant used as a % of the weight of latex

Anticoagulant	Dosage in the field		Dosage in the transportation tank		Method of Preparation of stock solution
	Recommended rate as a % of the weight of latex	Approximate equivalent in ml of the stock solution per litre of latex	Recommended rate as a % of the weight of latex	Approximate equivalent in ml of the stock solution per litre of latex	
Ammonia	0.01 - 0.05	10 - 50	0.005 – 0.01	5 - 10	1 kg of ammonia gas in 100 litres of water or one part of strong liquid ammonia with approximately 24 parts of water
Sodium sulphite	0.05 – 0.15	15 - 50	0.03 – 0.05	10 - 15	1 kg of sodium sulphite in 30 litres of water
Washing soda	0.025	15	.005	3	1 kg of washing soda in 60 litres of water

N.B. When the anticoagulant is not used in the field, it is advisable to use the higher dosage specified above during transportation.

Anticoagulants should be added to the latex as early as possible by adding to the collecting cups if possible. This is done by issuing each tapper with a small bottle containing the stock solution of anticoagulant. The bottle should be corked with a small hole in the cork, into which may be fitted a small spout. A few drops of the solution are shaken into the cup after the tree is tapped. In practice it is difficult to ensure this being done satisfactorily. Hence, it is advisable to add half the quantity of anticoagulant to the cups and the remainder to the latex collecting bucket.

Sodium sulphite is added in the field as a freshly prepared solution of 3.3%. If the latex collection vehicle arrives late at the factory, required dosages of sodium sulphite must be divided into 2 to 3 parts and added at different times as a freshly prepared solution; but increasing the dosage beyond recommendation is not effective at all.

6. TRANSPORTATION OF LATEX

Latex should be delivered to the factory as quickly as possible after collection, in order to avoid premature coagulation of latex meant for processing into sheet rubber, crepe rubber or TSR and to prevent VFA development in latex meant for processing into concentrated latex.

It may be necessary to have latex collection centres at central places in different divisions or in individual fields in estates. The latex brought in by the tappers should be weighed and poured into transportation vessels, after the addition of a suitable preservative, for delivery to the main factory.

The most convenient and economical method of transport of latex to the factory is by means of a bowser or trailer- mounted tanks.

6.1 Tanks for latex transport

Aluminium is the best material for the construction of tanks for latex transport. The essential feature is the provision of a large manhole so that the tank can be thoroughly cleaned each day after use.

Iron tanks, if adequately protected, could also be used for transportation of latex. The best way to protect them would be to coat the inner surface with an inert material which will prevent latex from coming into contact with the metal. Suitable coatings are inert paints such as epoxy paints and bitumen-based emulsions. Chlorinated rubber-based paints which are more expensive have the advantage that they are white; this colour has a psychological advantage as an incentive to cleanliness.

6.2 Cleanliness of transporting vessels

After unloading latex in the factory, transporting vessels should immediately be cleaned thoroughly. If these transporting vessels are kept unclean, bacteria will develop within the vessel causing putrefaction which will ultimately result in contamination of latex with bacteria. The end result is that precoagulation sets in and the crepe rubber manufactured with this latex may have streaks. Also the crepe rubber manufactured with latex highly contaminated with bacteria, though there is no visible precoagulation, may undergo discoloration. Collection of field latex in uncleaned utensils for manufacture of concentrated latex leads to a very high risk of VFA development beyond acceptable levels.

7. POST-COLLECTION OPERATIONS

7.1 Preliminary straining

On arrival at the factory (or collection station), the latex should receive a preliminary straining through a sieve fitted with monel metal mesh of 40 mesh size, in order to remove lumps, bark shavings etc. Brass mesh is unsuitable for this purpose, owing to the deleterious effect of even minute traces of copper on the quality of the rubber. For this reason, there should be no equipment containing copper or brass which comes into contact with latex or rubber during its processing. Stainless steel is also very suitable but more expensive.

7.2 Weighing

In Sri Lanka, the tappers are paid a daily wage and a bonus for every additional kilogram of rubber over the specified norm brought in by them. The usual procedure is to pour the latex into a standard bucket and measure the volume in litres using a dipstick. Alternatively, the weight in kilograms may be taken by hanging the bucket on a spring balance. The bucket, dipstick and the spring balance must be stamped by the Weights and Measures Division of the Department of Commerce, Sri Lanka. The DRC of a sample of the latex is then estimated by the metrolac or by trial coagulation and payment to the tapper made according to the calculated weight of the rubber. The standard metrolac chart shown in annex I is used to estimate the amount of rubber brought in by tappers after estimating the metrolac DRC (Plate 1.1a).

7.3 Estimation of Dry Rubber Content (DRC)

The DRC of field latex is not constant. At the first opening of the tapping cut the DRC is high and in subsequent tappings it falls until it reaches an equilibrium. In very dry weather the DRC is high and after prolonged rain or flooding it drops. Intensive tapping systems and the use of stimulants usually depress the DRC. Metrolacs are used to estimate the DRC of latex for the payment of tappers and as a guide to dilution prior to coagulation. It should be realised that the DRC estimated by the metrolac is not as accurate as the DRC determined by the laboratory method. However, the use of the metrolac is the most convenient, rapid and reasonably accurate method for the estimation of DRC of latex in the field. It is also important that the correct metrolac chart recommended by the RRISL should always be used for the calculation of the dry weight of rubber in latex. The recommended metrolac chart is given in annex I.

7.3.1 Metrolac method

The metrolac (Plate 1.1b) is a glass instrument which measures the density of field latex. The density of latex varies according to the amount of rubber present, and the instrument is graduated to give a direct reading of the rubber content of latex in grams per litre.

The latex should be diluted with two volumes of water before making the estimation, as the metrolc does not move freely in undiluted latex. The assumption underlying the use of the metrolac is that the relation between the density and the DRC of field latex is consistent, irrespective of the source and dilution of the original latex, an assumption which is not necessarily correct. The reason for this is that latex is a heterogeneous mixture consisting of various substances having different densities and the composition of latex varies on different estates, because of clonal, and soil variations. There is also a seasonal variation of the composition.

The metrolac does not work in latices of certain clones with a tendency to incipient coagulation. In such cases, an anticoagulant should be added to the latex in the field. All readings of the metrolac should be taken after ensuring that the instrument moves quite freely in the diluted sample of latex. Froth on the latex surface and the angle at which the reading is taken will influence the results. Fine air bubbles in latex due to pouring, stirring or shaking will affect the density of latex and consequently the reading of the metrolac. The reading on the stem should be taken at the bottom of the curve (meniscus), i.e. on a level with the surface of the latex (Fig.1.2).

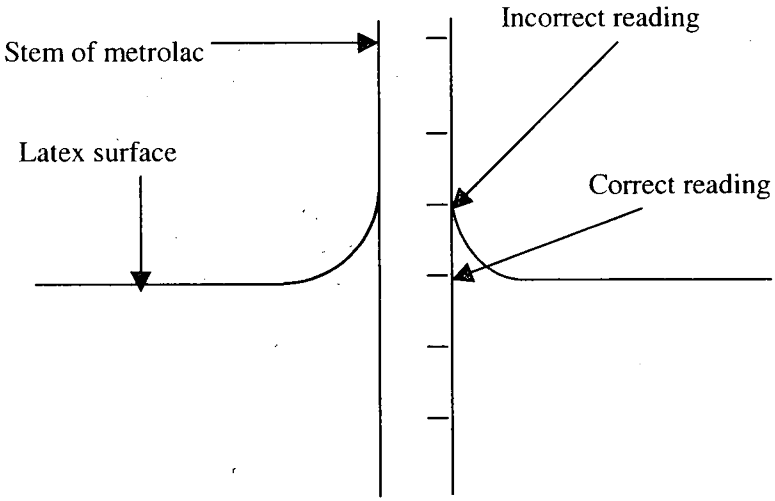

Fig. 1.2. Correct reading of the metrolac

It has been reported that the tappers resort to various malpractices to get a higher DRC for their latex. Adulterants such as starch and sap of certain plants are sometimes added to latex by tappers in the belief that they would appreciate the DRC and in fact the free movement of the metrolac is hindered when such materials are added to latex thereby giving erroneous readings, but depending on how the metrolac is inserted into latex the metrolac reading may be higher or lower than the correct value. They also adopt various methods to increase the temperature of latex and it has a direct effect on the metrolac reading. Therefore, if latex is found to be warm, the DRC should not be estimated using the metrolac and it is better still to reject the latex. The variation of the metrolac reading with the temperature of latex having a DRC of 31% is shown in figure 1.3.

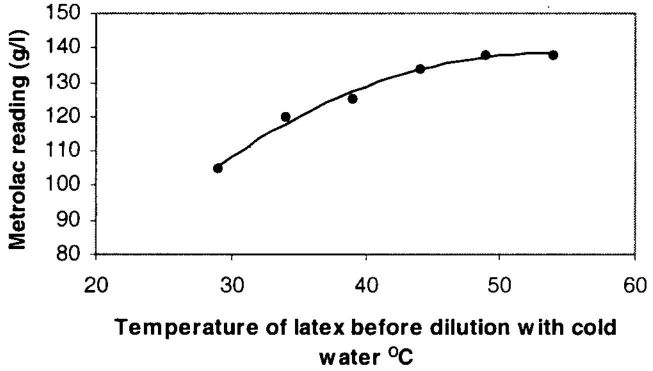

Fig. 1.3. Effect of temperature on metrolac reading of unstabilised field latex

7.3.2 Trial coagulation method

There are two methods of carrying out trial coagulation determinations. These two methods are suitable for use in estates.

7.3.2.1 Estate method of trial coagulation

The metrolac reading of a sample from the bulked latex is taken, after dilution with two volumes of water. Another sample of the bulked latex is diluted with one volume of water and 5 litres of it is poured into a coagulating pan. The measure is rinsed with 250 ml of water which is added to the latex. A second quantity of 5 litres of diluted latex is measured in the same way and poured into another pan. The latex in each pan is then coagulated by adding 500 ml of a 1% solution of formic acid (made by adding 12 ml of 85% strong acid to 1 litre of water) and stirring with a suitable paddle. When coagulation is complete, the coagulum is rolled either in a sheet roller or in a creping mill. In the latter case, care is required that none of the sample is lost; the rollers should be opened slightly to reduce the pressure on the rubber. After drying, the samples are weighed together on an electronic top-pan balance accurate to 10 g. The combined weight represents the rubber content of the original undiluted latex in grams per litre. The accuracy of the trial can be checked by weighing the two samples separately. If they differ by more than 10 g the test should be repeated.

7.3.2.2 The Chee method

A dipper calibrated to deliver 40±0.5 g of field latex is used. This is immersed slowly in a representative sample of latex. One dipper full of latex is drawn out gently and transferred to a coagulating dish. A mixture of 10 parts by volume of 10% formic acid and 90 parts by volume of methylated spirits is used for the quick coagulation of latex. The coagulum is fed through a pair of rollers a number of times at different gap settings. The coagulum is washed and pressed between blotting paper to remove as much water as possible, before it is weighed on an analytical balance. The DRC of latex is obtained by multiplying the wet weight of the coagulum by a factor determined previously by a trial experiment.

7.3.3 Laboratory methods for DRC determination

Three laboratory methods for the determination of DRC of field latex are described below. The second and the third methods are very fast but not as accurate as the first method unless tests are performed by experienced personnel with utmost care.

7.3.3.1 Standard laboratory method

A test portion of 10±2 g from a representative sample of latex, accurately weighed by difference, using a 50 ml weighing bottle, is poured into a petri dish having a diameter of 5 cm. The latex is coagulated using sufficient acetic acid and heated over a steam bath until a clear serum is obtained before it is pressed with a glass stopper to a thickness of approximately 2 mm. The coagulum is thoroughly washed and placed in a thermostatically controlled oven at about 70°C. After drying, the rubber is cooled in a desiccator and weighed using an analytical balance. Drying and weighing procedures are continued until the coagulum is dried to a constant weight and the dry rubber content is calculated from the above data.

7.3.3.2 Rapid laboratory method using air circulating oven

A representative sample of latex in a cylindrical plastic vial (about 2 ml capacity) is weighed together with a glass dropper using an analytical balance. From the glass dropper, approximately 0.5 g of the latex is added drop-wise onto a glass plate and immersed in a mixture of five parts by volume of glacial acetic acid and 95 parts by volume of methylated spirits in a petri dish. The dropper, together with the balance of latex, is reweighed to obtain the weight of latex transferred. Pieces of coagulum on the glass plate are pressed carefully and washed with distilled water before it is dried in an air circulating oven. The dry film on the glass plate is rolled off and weighed using an analytical balance.

7.3.3.3 Rapid laboratory method using microwave oven

Two to three drops of latex from a representative sample are carefully taken into a small petri dish (diam. 25 mm) and weighed on an analytical balance. A few milli-litres of 5% alcoholic solution of acetic acid are poured into the dish so that latex is completely covered with the coagulant. Press the coagulum carefully with a glass stopper till all the latex trapped inside the coagulum is completely coagulated and a very thin film of the coagulum is obtained. The film is carefully washed thoroughly in running water and dried using a microwave oven at medium power level for a period of 10 minutes initially. The film is then turned over and dried again in the oven for 5 minutes. Make sure that there are no white spots on the film. It is cooled in a desiccator before weighing and then the DRC is calculated. Carry out the procedure in triplicate. If the DRC calculated on three samples differs by more than 0.5% the procedure has to be repeated.

Plate 1.1. **a** Measuring and weighing of field latex at the factory; **b** Reading with the metrolac.

Chapter 2

Ribbed smoked sheets*

U.N. Ratnayaka

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* Adapted from "A Handbook of Rubber Culture and Processing", 1983

1. INTRODUCTION

In Sri Lanka, Ribbed Smoked Sheet (RSS) is made mainly by small-scale and medium-scale producers and there are only a few estates that manufacture more than 1000 kg per day.

The main factory operations involved are:

i. coagulation of suitably diluted field latex and preparation of sheets
ii. drying of sheets in smoke houses

The type of equipment required for the manufacture of RSS will depend mainly on the size of the crop to be handled. Basic requirements are receptacles for coagulation, machinery for milling and a smokehouse for drying.

2. STANDARDIZATION OR DILUTION OF LATEX

The latex is diluted to a standard DRC by the addition of fresh clean water. The DRC of field latex is reduced to 12.5% by diluting with a sufficient quantity of water prior to coagulation (Annex II). Dilution also assists in the more uniform distribution of acid and other chemicals and reduces the incidence of bubbles in the final sheets; thus the viscosity of the latex is reduced and trapped air and any fermentation gases can escape to the surface more readily.

The formula given below can be used to determine the quantity of water required to dilute the latex to reduce its DRC to the required level.

$$V_w = V_f\left(\frac{d_f}{d_s} - 1\right)$$

Where V_w = Volume of water required for dilution
V_f = Volume of field latex
d_f = DRC of field latex
d_s = DRC of standardised latex

For example, the volume of water required to standardize 350 litres of 25% DRC latex to 12.5% DRC latex is

$$V_w = 350\left[\frac{25}{12.5} - 1\right]$$

$$= 350 \text{ litres}$$

Certain clonal latices are prone to enzymatic discolouration resulting in the darkening of the RSS. This can be checked by the addition of a dilute solution of sodium bisulphite or metabisulphite at the latex stage prior to coagulation. The normal dosage is about 50 g of the chemical per 100 kg of dry rubber, added as a 1% solution. In the case of pronounced enzymatic discolouration this treatment should be carried out without any delay at the processing centre. Usually this treatment is not necessary in RSS manufacture but could be used effectively in the case of severe discolouration of certain latices.

3. COAGULATION OF LATEX

3.1 Receptacles

3.1.1 Pans

For small scale RSS manufacture, the latex is commonly coagulated in flat pans, each holding about 5 litres of diluted latex. Aluminium pans are widely used for this purpose. Pans made of plastic or thermoplastic natural rubber could also be used.

The internal dimensions of the coagulating pans usually sold in Sri Lanka are 400 mm x 325 mm x 65 mm deep. For durability, pans of adequate thickness to resist bending or denting should be purchased. The standard 21-gauge metal is recommended.

3.1.2 Troughs

Small-scale as well as medium-scale manufacturers use long troughs holding 22.5 litres of diluted latex. These are better than pans as they save a lot of handling. The troughs should be aluminium and the dimensions approximately 1.5 m long, 0.3 m wide and 75 mm deep. Wooden troughs are also used, but they are difficult to clean.

3.1.3 Tanks

The only practical method of coagulation for medium - or large-scale manufacture (200 kg and over per day) is to utilize tanks in which vertical partitions, placed in position after the addition of acid to the latex, divide the coagulum into slabs of suitable dimensions for machining using a sheeting battery.

In its usual form, the coagulating tank is constructed of aluminium and provided with aluminium partitions, which slide into grooves in the sides of the tank. Alternatively the partitions may be held in place by a frame which rests on the top of the tank. The coagulating tank could also be constructed with teak or other hardwood in which case the inside surfaces should be lined with aluminium sheeting.

The standard size of a coagulating tank is 3 m long x 1 m wide. The depth depends on the size of the sheeting mill and ranges from 350 to 450 mm. In most cases the depth of diluted latex in each coagulating tank does not exceed 400 mm, so that the slabs of coagulum are approximately 350 mm wide. The capacity of a tank of this size is approximately 1000 litres. As each tank is fitted with 90 partitions, there would be 91 slabs of coagulum. It would be preferable to have castors (wheels) fitted on to these tanks, so that they could be moved into position close to the sheeting battery. Alternatively, if the tanks are immovable a central chute may be necessary to have the coagulum floated to the sheeting battery.

A minor drawback in tank coagulation is the fact that the side of the coagulum which is uppermost in the tank is harder than the bottom. This is the result of natural consolidation of the coagulum owing to the buoyancy of the rubber, but the effect may be increased by the occurrence of anaerobic fermentation at the bottom of the tank, tending to make the lower part of the coagulum spongy. One side of the finished sheet is usually correspondingly thicker than the other, which should be corrected manually by hand pressing, as sheets of uneven thickness passing through the battery tend to tear.

3.2 Coagulants

Formic acid is the preferred coagulant used in RSS manufacture. Acetic acid could also be used but the concentration should be doubled as acetic acid is a weak acid compared to formic acid.

3.2.1 Acetic acid

Acetic acid is not favoured as a coagulant, as the rate of coagulation with acetic acid is rather slow and under certain conditions this gives sufficient time for the latex to ferment, causing discoloration of the coagulum and bubble formation in the sheets. The underside of the coagulum has a mucilaginous appearance which is especially pronounced in pan coagulation and the RSS may be found to be dark in colour. These defects may be prevented by using formic acid in place of acetic acid as the coagulant. It may be mentioned that formic acid also has antiseptic properties whereas acetic acid may stimulate development of bacteria. Acetic acid is not used in the rubber industry in Sri Lanka.

3.2.2 Formic acid

Commercial formic acid has a strength of about 85%. The quantity of formic acid required for coagulation where rolling is carried out on the day following coagulation is about 350 to 450 ml of strong acid per 100 kg dry rubber. If the sheets are to be rolled the same afternoon, the amount of acid is approximately 475 to 550 ml per 100 kg of dry rubber. The acid should be added in the form of a 1% solution. For the preparation of 1% solution, 1 part of the acid should be diluted with 84 parts of water. It has been found on numerous occasions that the quality of the RSS is considerably improved by changing from acetic to formic acid. The quality of the sheets can be improved to some extent if the coagulum is rolled the same evening and put in the smoke house for smoking the same night.

3.3 Coagulation process

3.3.1 Pan or trough coagulation

The coagulant and latex should be mixed in Shanghai Jars or other suitable vessels e.g. tanks lined with glazed tiles of a capacity not exceeding 250 litres. After addition of the acid and thorough stirring, the latex should be distributed to the pans or troughs as quickly as possible in order to avoid premature coagulation. With good organization, distribution of the latex should be completed within 6 to 7 min after adding the acid. It is not necessary to continue to stir the latex in the mixing vessel while it is being distributed. This tends to make the latex clot more rapidly. It is preferable to have the pans arranged on shelves and to carry the latex to the pans in buckets, rather than to bring each pan to be filled.

It has also been observed that sometimes clotting sets in before the distribution of latex is complete. In such cases smaller quantities of latex should be dealt with, or it may even be necessary to distribute the latex to pans before the addition of the acid. The pans are stacked one over the other in groups of 10 to 15 (Plate 2.1a). It is essential to ensure that the pans are stacked in a true level, otherwise the coagulum will be uneven in thickness resulting in uneven rolling and the thicker end of the sheet will not dry and will therefore have to be cut off.

3.3.2 Tank coagulation

The quantity of standardized latex is so adjusted that after the addition of the required quantity of diluted acid, the depth of the latex does not exceed 350 mm. The acid is poured in and the latex thoroughly stirred with a wooden or aluminium paddle. Froth is removed (Plate 2.1b) from the surface and the partitions placed in position. When inserting the partitions they must be placed at random and not in a definite order.

If the outlying divisions are not too distant from the main factory, it would be preferable to transport latex rather than the coagulum. However, precoagulation, which is one of the primary causes of off-quality RSS, must be carefully controlled. In the event of precoagulation in spite of precautions taken, the only treatment is to remove the precoagulated rubber and to coagulate the balance of the latex as for normal RSS manufacture. The precoagulated rubber can be used in the manufacture of lower grades. If coagulum has to be transported, then the coagulated slabs may be placed one on top of the other, care being taken to ensure that not more than six slabs are piled over one another. In this method of transport the coagula may stick to one another and it may be difficult to separate the slabs. If this occurs rolling will not be satisfactory and the quality of the sheets produced will be adversely affected. This difficulty can be eliminated to some extent, if the slabs are first passed through a smooth sheeting mill with only a mild pressure applied, before transport.

3.3.3 Removal of froth

The mixing of coagulant and latex and distribution to pans produce a considerable amount of froth. If not removed, this causes pitting of the surface of the sheets when the coagulum is rolled. The froth is therefore skimmed off by means of a suitable skimmer such as a piece of smooth board or aluminium or galvanized iron sheet of at least half the width of the tank or pan in length (Plate 2.1c).

3.4 Control of latex coagulation

The amount of acid required for coagulation of latex is not a constant figure, but depends on various factors such as amount and type of anticoagulant used in the field, clone, weather, quality of the water used, distance to the factory, dilution, time of coagulation, etc., and may therefore vary from day to day. These factors make it difficult for the factory officer to determine daily the optimum amount of acid required for coagulation. Experience may enable him to estimate the required amount, but sometimes this may result in too much acid giving a hard coagulum which may cause difficulties in the milling of sheets or in too little acid resulting in a milky serum, entailing loss in rubber and liability to bacterial action.

Both extremes, too much or too little acid, negatively affect the quality of the final product and reduce the No 1 percentage of rubber. A well-performed coagulation should give a clear or slightly opaque, yellowish coloured serum.

The coagulation of field latex by addition of acid is due to a reduction in pH which results in equalization of the negative and positive charges on the proteins adsorbed on the rubber particle. The pH at which the negative charge is balanced by the positive charge is known as the isoelectric point of the protein. A medium having a pH higher than the isoelectric point is alkaline to that protein and the protein shows a negative charge whereas a medium having a pH lower than the isoelectric point is acidic and the protein shows a positive charge. The isoelectric point of the surface active protein on the rubber particles in field latex lies between pH 4.4 and 4.8. The latex coagulates in this pH range.

Depending on the required hardness of the coagulum and the milling, viz. the same day or the following day, the suitable pH for coagulation is approximately between 4.4 and 4.8. In order to ensure a proper coagulation it is therefore desirable to control the pH of the latex during the addition of the coagulant. A simple and quick determination of the pH can be done by means of Bromo Cresol Green (BCG) indicator paper, which changes colour according to the pH, from blue through bluish green and yellowish green to yellow (Fig.2.1).

Coagulation at pH 4.8 proceeds quite slowly, resulting in a soft coagulum suitable for RSS manufacture. The serum may be slightly milky and the colour of the BCG indicator paper will be bluish green. If the pH is lowered to 4.6 the serum will be clear and the coagulum would also be suitable for RSS manufacture, and the colour of the BCG indicator paper will be green. A lowering of the pH to 4.4, giving a yellowish green colour to the indicator paper, produces a clear serum and a harder coagulum, not suitable for RSS manufacture. A blue colour indicates insufficient acid and a yellow colour indicates an excess of acid, not suitable for RSS manufacture.

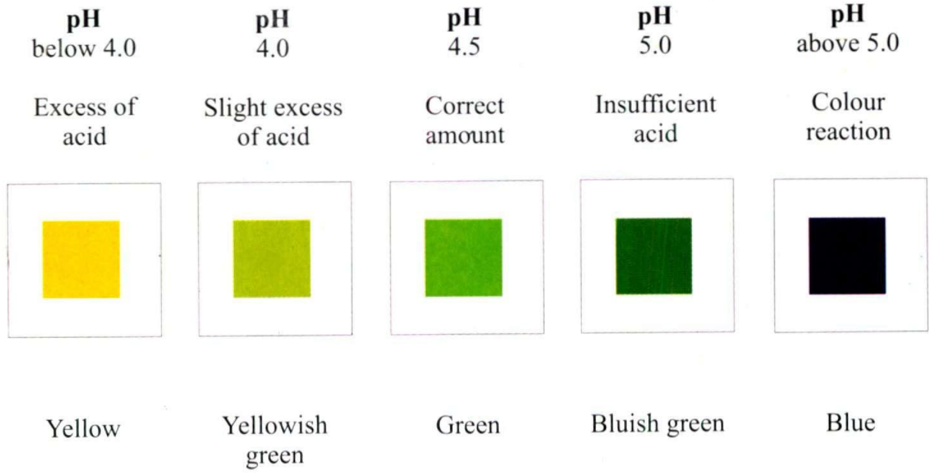

Fig. 2.1. Colour chart for BCG indicator paper for the determination of the optimum amount of acid to be used in factory coagulation of latex

BCG test paper is best used by placing the surface of the paper strip over the latex, after removal of froth. One side will be coated with the latex and the colour indicating the pH will be clearly visible on the other side. Dipping into the latex will obscure the colour. If the latex is spotted on the indicator paper, the spot produced may vary in colour from the centre outwards and some difficulties may be experienced in deciding the correct shade showing the actual pH.

4. MILLING

4.1 Machinery

4.1.1 Hand or power operated rollers

Equipment consisting of one or more smooth rollers and marking rollers, operated by hand or power is suitable for handling crops up to a few 100 kg daily. The coagulum is rolled in the smooth rollers (Plate 2.2a) two to three times, the space between the rollers being altered after each milling and is then passed through the marking roller.

This method is reasonably satisfactory for small crops, although the frequent adjustment of the rollers causes the parts to wear quickly and often there are differences in thickness of the sheets, which lead to uneven drying and smoking. It is preferable to pass the sheets through the machine in batches, so that the alteration of the setting of the rollers is reduced to a minimum.

The rollers should be fitted with a water spray so that the serum is washed off from the sheet as it is squeezed out. This is also effective in preventing corrosion of the rollers. The width of the rollers should be about 50 to 60 cm and the diameter about 9 to 11.5 cm. The output obtainable from one smooth and one marking roller (hand operated) is 50 to 70 sheets per hour.

If hand-or power-operated sheeting mills are used for rolling coagulum prepared from tanks, there would be over-handling of the coagulum and this will result in a high percentage of cuttings and clippings in the finished sheets.

4.1.2 Batteries

A battery consists of three or four pairs of smooth rollers and one pair of spirally grooved rollers mounted as a unit in line-ahead formation (Plate 2.2b).

The rollers are geared together and the speeds and settings are so adjusted that the coagulum passes through the machine without tearing or backing up and emerges as a finished sheet. The rollers are provided with water sprays. These rollers may be from 60 to 75 cm in width, and 15 cm in diameter. Power requirements vary from 5 to 7 HP. The type of battery suitable for medium-scale producers would be the four-roller sheeting battery, which has an output of approximately 300 kg per hour.

4.1.3 Grooving of marking rollers

A suitable pattern for the rollers of the marking machine consists of spiral grooves, always cut in the same direction, at 45° across the face of the rollers. The grooves should be 3 mm in width and depth and square cut, with 3 to 4.5 mm between the grooves.

4.1.4 Care and maintenance

Rollers should be thoroughly washed each day after use. It is also desirable to wipe the rollers with a cloth moistened with a dilute solution of washing soda (20 g per litre of water) in order to remove any acid which remains. The rollers should then be thoroughly rinsed to remove all traces of soda solution and dried as far as practicable.

Grease or oil for bearings should not be used in excess, since contact with grease or oil causes deterioration of the rubber. However, lubrication should be done frequently for smooth operation of the rollers.

Worn parts of machines should be replaced and rollers re-machined periodically. Worn machines make rubber of inferior appearance and are likely to lead to problems in the smokehouse owing to uneven drying.

4.2 Rolling process

Preliminary hand rolling produces a firm coagulum, which is easier to work on the machines, but it is not an essential operation. The coagulum should be placed on a table between two reepers which are nailed down leaving a space slightly wider than the coagulum. The coagulum is then hand – pressed down to a thickness determined by the height of the reepers.

If the coagulum is pressed by hand, it should be done carefully and uniformly. Suitable manipulation assists in preventing thick edges in the finished sheets. Heavy kneading is not recommended and is likely to lead to uneven drying.

The rate of drying is mainly determined by the thickness of the sheets. This should correspond to a dry weight of 200 – 225 g per 900 cm^2. The average thickness of sheets after smooth milling should be 2.5 mm.

4.3 Washing of sheets

The sheets must be well washed during milling and should be soaked in running water for a short time after milling. Hand operated mills should be fitted with water sprays at their nips. There should always be plenty of water on the mills.

5. DRAINING OF SHEETS

The dripping time of the sheets should not exceed 3 hours. Wet sheets may be allowed to drip either by hanging them on reepers, preferably in a draft in the shade (Plate 2.3a) or by stacking them in suitable piles on a sloped platform. The floor of the platform may be made of 5 cm reepers that will allow the surface moisture to drain off quickly. The slope of the wooden platform may be about 45°. If a tunnel type smoke house is available, dripping can be done on trolleys keeping them in the verandah of the smokehouse. This is the most efficient method of draining sheets as further handling of the dripped sheets is avoided. The wet sheets should be inserted immediately after dripping into a warm smoke house and a smoking temperature of 48° – 54 ° C must be obtained shortly after insertion. Undue delay in transferring the sheets to the smoke house or in getting the temperature of the smoke house to 48° – 54° C will lead to the development of rust on the sheets.

6. SMOKING AND SMOKE HOUSES

The purpose of the smoke house is firstly to dry the sheets and secondly to enable the sheets to absorb creosotic and other antiseptic substances which have a preservative effect on the rubber. These substances prevent or retard the development of mould and other microorganisms. The smoke also has an antioxidant effect and it dries the sheets at a high temperature without making them sticky as would otherwise be the case. The antiseptic value of the smoke varies according to the way the wood is burned. A hot bright fire produces a light pungent smoke deficient in antiseptic substances, whereas a smouldering fire produces a heavy smoke, giving the sheets a somewhat unattractive appearance and leads to problems with reeper marks.

A smoke house should be located at least 15 metres from any other building. Failure to observe these limits could lead to a considerable increase in insurance premia on neighbouring buildings.

The two most common faults encountered in the construction of smoke houses are, (1) failure to seal the space between the ceiling and the roof, and (2) failure to provide good drainage on the floor, e.g. in tunnel type smoke houses at the cool end of the smoke house. The former fault allows moisture to condense on the ceiling from the humid smoke house atmosphere. This moisture then absorbs dark coloured substances from the smoke and drops from the ceiling on to the sheets causing dark sticky stains. This problem can usually be eliminated by sealing the space between the ceiling and the roof near eaves, or by having a fairly large clearance between the ceiling and the roof. The other fault is difficult to rectify in a finished smoke house; therefore, care should be taken during construction to see that drainage is sufficient. When wet sheets warm up after being placed in the smoke house, several litres of water are eliminated from the rubber within a few hours by "sweating" and dripping. Drains should convey this water outside the smoke house as quickly as possible.

6.1 Types of smoke houses

Basically there are two types of permanent smoke houses used in Sri Lanka viz:

(1). Smoke houses operated by internal pit furnaces or trolley box furnaces
(2). Smoke houses operated by external furnaces

6.1.1 Pit-fired smoke houses

This type of smoke house is mainly recommended for small crops i.e. 160 – 360 kg and plans of such type smoke houses are available at RRISL. Smoking can be completed in 5 to 6 days. The pit–firing system consists of a central pit, usually inside the smoke house. This type of furnace has the disadvantage of being difficult to clean out and to stoke. There should be a minimum space of 2 m between the fire and the nearest sheet. A baffle plate of heavy gauge metal or galvanised iron slightly larger in size than the mouth of the pit should be fixed about 25 cm above the pit so as to spread the smoke and heat.

6.1.2 Trolley box furnace type smoke houses

This smoke house known as the Rubber Research Scheme (RRS) type, comprises a building of two or three storeys, including the furnace room at ground level. Heat and smoke are generated in a fire trolley on wheels which can be drawn on to a verandah for replenishment. This method of firing minimizes dust in the smoke house.

The walls may be constructed of stone, brick or cement-sand bricks, with or without a steel frame. Weather boarding and corrugated iron sheets are not favoured owing to the risk of side draughts interfering with ventilation. The roof may be of tiles, or corrugated asbestos or galvanised iron sheets. It is important for the top storey to be effectively sealed except for an adjustable ventilator. Doors and windows should fit well.

Ventilation to the furnace room is provided by vent pipes spaced at intervals round the wall. They should extend well into the building so that the air is directed towards the fire trolley and bends should be fitted outside the wall to prevent a direct draft through the building on windy days. A smoke outlet with a sliding shutter is provided at the apex of the roof.

The smoking racks are arranged so that the sheets are hung at right angles to the passages (Plate 2.3b). Round "reepers" of 2.5 cm diameter are arranged loosely extending 3.5 cm into the passages, so that the sheets can be moved by rotating the reepers. "Reepers" are spaced 7.5 cm apart from the centres and hanging space is provided on the basis of 500 g sheets rolled to standard dimensions. "Reepers" of arecanut or jungle wood are fairly satisfactory if they are allowed to season for some time before use. "Reepers" need removal at least once a month for washing and drying as by usage they get impregnated with serum substances and smoke deposits which will result in defects of the finished smoked sheets. Hence it would be preferable if there is a stock of extra reepers for the smoke house. Passages of liberal width and shuttered windows are provided in the hanging lofts. It is essential to minimise the inconvenience of handling the sheets as far as possible and to have ample light for rotation and removal of sheets.

Smoking can be completed in 5 to 6 days if the sheets are of standard thickness, free from thick edges and if the period for changing sheets, etc., is limited to about 4 hours daily. The temperature should be maintained at 48-54 °C in the hanging lofts.

6.1.3 Smoke houses operated by external furnaces

The capacity of smoke houses which have been operated by pit-fired furnaces can be increased by replacing the internally fired pit furnace with an external furnace (Plate 2.3c). Plans of such type of smoke houses with external furnaces and capacities ranging from 1000 to 1600 kg are available at the RRISL.

6.1.4 Tunnel type smoke houses

This type of smoke house consists of a tunnel-like building designed for a daily output of 500 kg and is about 12 m long, 2.5 m wide, and 5 m high (to the eaves). A light rail track is laid down in the centre of the building and the sheets are hung on four trolleys, which completely fill the building. Smoking is completed in 4 days and each trolley holds a single day's crop. The sheets are hung on a trolley direct from the rolling mill and after a period of dripping and surface drying, the trolley is pushed into the smoke house at the cold end; it should be then moved daily towards the hot end after introducing each day's trolley from the cold end.

The smoke house is heated by means of an outside furnace located at the side of the building near the end at which the finished sheets emerge and the smoke from the furnace passes through a flue which runs the length of the building between the rails, with outlets under the centre of each truck. Efficient smoking depends mainly on correct smoke house temperatures. Experience has shown that the temperatures during the 4 - day drying cycle should be 48°C – 52°C on the first day, 52 °C – 54 °C on the second, 54° - 57 °C on the third and 57° - 60 °C on the last day. These temperatures can usually be obtained in the tunnel type smoke house by setting the smoke outlets (in the floor) fully open at the cool end and one eighth open at the hot end, with intermediate settings for the outlets in between. Similarly, the settings for the roof ventilators are three quarters open at the cool end and fully closed at the hot end, with intermediate settings for the ventilators in between. These settings are given as a starting point; when trying to obtain the correct temperature they may require small adjustments after trial. A recording thermometer allows a close check on temperature fluctuations in the smoke house, but indications on maximum and minimum thermometers are sometimes sufficient.

The roof may be of tiles, asbestos or galvanised iron sheets. Effective internal sealing must be provided. The furnace comprises an outer casing consisting of brick walls, with a top of reinforced concrete. This shell encloses a brick arch tapering down towards the flue, which forms the furnace proper. Heat radiated from the outer surface of the furnace arch is collected by a stream of air which passes between it and the outer shell, and hence into the flue, where it mingles with the smoke from the fire. The front of the structure is closed with a face plate which is bolted on and carries a furnace door and two adjustable ventilators one on each side, to supply air between the fire arch and outer case. The important features of this design are, firstly, only heated air passes into the smoke house and secondly, the inner walls of the furnace do not become so hot that insufficient smoke is produced.

A minor drawback, which has been noted locally, arises from the fact that there is a greater day – to day variation in crop here than in Malaysia. The result of a day without crop (owing to rain) is an empty trolley and this upsets the adjustment of ventilation and temperature. A similar but less pronounced effect is found when one or more of the trolleys are only partially filled. If large crops are being handled the difficulty can be overcome by providing two or more smoke house units, so that the number in use can be regulated according to the crop. Otherwise the sheets should be spaced out on the trolleys as evenly as possible and the ventilators regulated as required.

The tunnel type smoke houses though more costly to build, have the following advantages over the Rubber Research Scheme (RRS) type smoke houses:

- They need less labour for operation
- They have a shorter drying cycle and are nearly continuous in operation. RRS type smoke houses have to be operated at a lower temperature and the heating operation has to be stopped each day to change the sheets
- The temperatures are more easily controlled. Hence tunnel type smoke houses should be an economic proposition for an estate turning out over 500 kg of RSS per day.

6.1.5 Modified RRS type smoke house

This smoke house comprises a building of three storeys including the room at ground level. The trolley box furnace of the RRS type smoke house has been replaced with an external brick furnace and underground flues. The trolley box and furnace room have been converted into an additional smoking space giving an approximately 50% increase in capacity. Plans of three-storeyed smoke houses are available for a range of capacities from 750 kg to 3500 kg at the RRISL. This type of smoke house is unsuitable for sites with a high water table, since the furnaces and flues are below ground level.

6.2 Operation of smoke houses

6.2.1 Ventilation

The primary purpose of smoke–curing of rubber is to dry the sheets and efficient ventilation should be provided in order to carry away the moisture as quickly as possible. If it is generally realised that each wet sheet placed in a smoke house contains approximately 175 g of water and that at a temperature of 48°C its removal requires at least 1.8 cubic metres of dry air, there would be less tendency to imprison the saturated smoke in smoke houses. In a smoke house containing 3000 sheets, a minimum air flow of 1000 cubic metres per day is required if the sheets are to be dried in 5 days. This figure is based on the assumption that the air is dry when it enters and completely saturated with moisture when it leaves the smoke house. In actual practice the flow of air required would be more than double this figure. On the other hand, nothing is gained by excess ventilation, since the time of drying is mainly governed by the rate at which the moisture diffuses from the interior of the rubber to the surface. All that is required is sufficient air movement to ensure evaporation of the moisture as it reaches the surface. Restricted air movement leads to trouble with "rust" and other defects. Excessive ventilation is wasteful of heat and smoke. Ventilation depends on the rate of air flow into the building and the rate of air flow out of the building. This should be controlled by regulating the rate of outflow of the smoke at the apex of the building. There is then no disturbance of air flow when the doors are opened for stoking the furnace or for other purposes. If, on the other hand, the air inlet is restricted, opening of the doors will lead to a sudden rush of air through the building. The air inlet space at the base of the building should amount to approximately 0.2 square metres per 100 cubic metre capacity of the building, and the air outlet space in the roof to 0.2 square metres per 200 cubic metre capacity. The outlets should be capable of adjustment by sliding shutters or other means. Plans of the RRS and tunnel smoke houses make suitable provision for ventilation. The above notes may, however, be of use in connection with existing buildings. Great caution is necessary in making alterations since, for example, an increase in bottom ventilation without restricting top ventilation would lead to an increased draught and the risk of fire with certain types of furnaces.

6.2.2 Furnaces

Modern smoke houses are heated either by means of a fire trolley which can be withdrawn for stocking (RRS type) or an external furnace. With either type of furnace it is important that ventilation of the fire should be separated from the main ventilation of the smoke house, i.e. it should be possible to increase or decrease the amount of air passing through the building, without influencing the fire in the furnace.

6.2.3 Fuel

Rubber and jungle wood are suitable for smoking. Wet or green wood causes the sheets to have a glossy or greasy surface and reduces the drying capacity of the air. It is permissible to add a small proportion of coconut husks, paddy husks or shells of rubber pods to the fuel, but the appearance and smell of the rubber may suffer if large quantities are used.

About 0.5 to 2.0 m^3 firewood are needed to smoke 500 kg of rubber assuming a 6 - day smoking period. About 0.5 - 1 kg of firewood is needed to smoke 1 kg of rubber.

6.2.4 Temperature and temperature control

The temperature in smoke houses of the RRS and similar types should be maintained at 48° – 54°C. The temperature should not be too low, as the rate of diffusion of moisture through the rubber is largely governed by the temperature.

Every smoke house should be provided with a maximum and minimum thermometer, which should be so enclosed that it can be read but cannot be tampered with.

A more efficient method of temperature control is provided by a recording thermometer, with the dial placed outside the smoke chamber. This instrument provides a continuous temperature record and thus indicates whether the smoke house is being operated at maximum efficiency. The 8-day type of recorder is most suitable for estate use.

The work in the smoke house should be organised in such a way as to ensure its continuous operation for at least 20 hours a day and the temperature is maintained constantly within the range of 48° – 54°C. Prolonged drying due to part-time operation of the smoke house or reduction of the recommended drying temperature, is an important factor which leads to defects. Sometimes, the work in the smoke house, such as turning over the sheets, removal of dry sheets and insertion of the wet sheets is unduly held up until late in the afternoon. Firing should be done on a little and often basis, i.e. to and two to three logs of firewood every few hours and refrain from stoking the ovens except only once or twice a day.

7. UTILISATION OF SUNLIGHT FOR DRYING OF SHEET RUBBER

It was a belief among rubber technologists that exposure of raw rubber to direct sunlight causes deterioration in quality causing tackiness. However, recent experimental results indicate that sun drying of ribbed sheet rubber for three to four days for complete dryness will not adversely affect the physical or vulcanizate properties of the rubber, but in order to eliminate mould contamination of the sheet rubber, smoking in a smoke house for one to two days is recommended.

After milling the coagulum through smooth and diamond mills respectively, the ribbed sheets could be hung in an open area where sunlight directly falls on to the sheets. Drying is continued for two or three days under direct sunlight and then the sheets are smoked in a smoke house for one or two days continuously. It is advisable to turn the sheets everyday to prevent tackiness caused by over heating certain areas of the sheets. Final smoking in the smoke house will give a honey–brown appearance to the sheet and protection from mould growth on the surface. However sun-dried sheets may be more susceptible to mould contamination than smoked sheets.

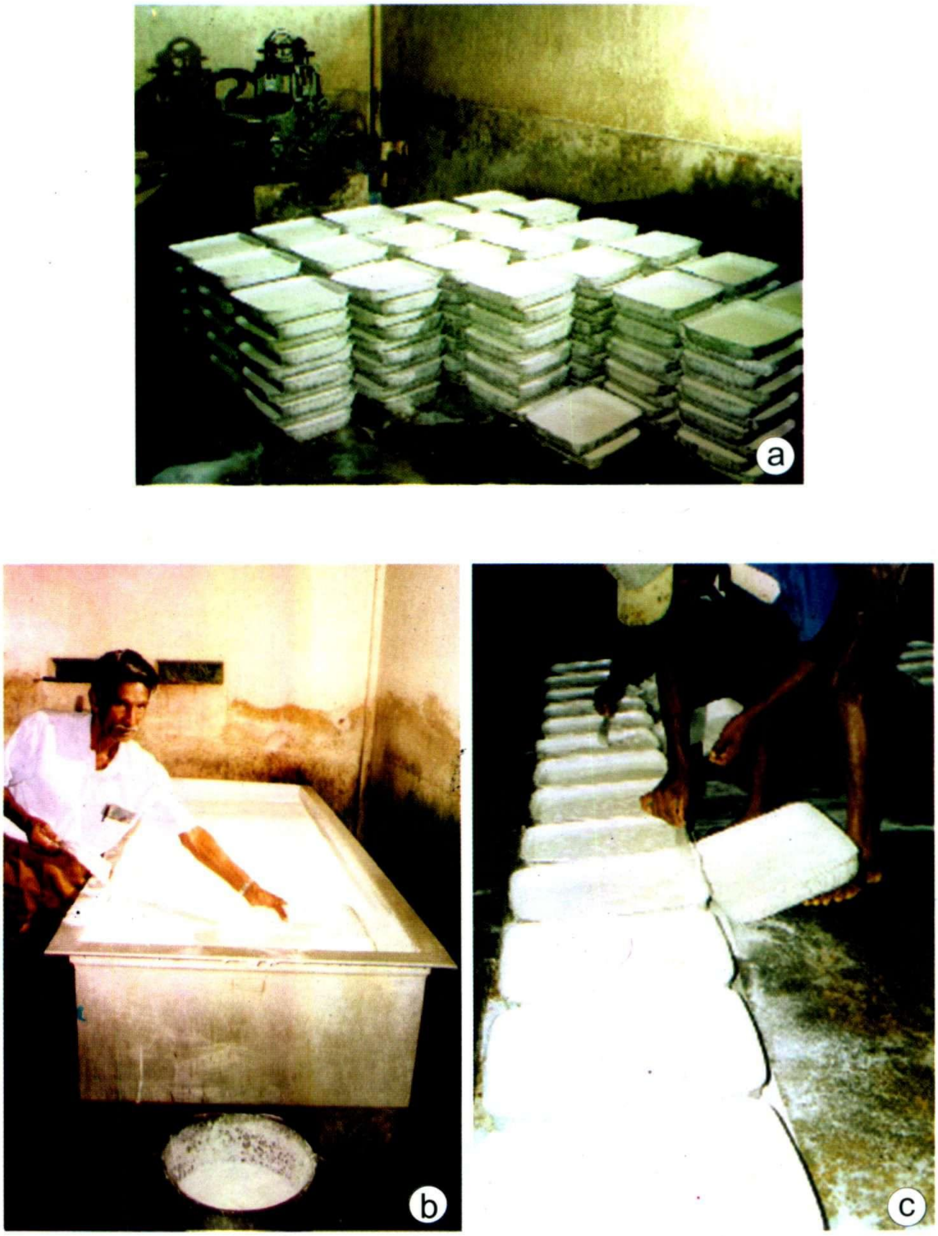

Plate 2.1. Coagulation of latex. **a** Stacked coagulating pans with acidified latex; **b** Removal of froth in tank coagulation; **c** Removal of froth in pan coagulation.

Plate 2.2. Mills used in sheet manufacture. **a** Hand operated smooth mill; **b** Power operated battery of rollers.

Plate 2.3. Draining and smoking. **a** Dripping of sheets; **b** Racks inside the smoke house; **c** External furnace of a smoke house.

Chapter 3

Pale crepe and sole crepe*

W.M.G. Seneviratne and P.H. Sarath Kumara

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* Adapted from "A Handbook of Rubber Culture and Processing", 1983

1. INTRODUCTION

Latex crepe is the purest form of natural rubber available in the market and Sri Lanka is the world's leading producer of pale and sole crepe for the export market. Sri Lankan crepe has a high level of cleanliness unsurpassed by any other grade of NR. It is manufactured in the plantations under clean, hygienic and carefully controlled conditions.

Pale crepe is mainly used in non-black applications and the vulcanisate of pale crepe has excellent tack, green and hot tear strengths.

Pale crepe does not contain any leachable chemicals and the protein level naturally present in rubber is reduced to a minimum during the production of this grade. Hence latex crepes (thick and thin grades) are speciality grades of rubber made, *inter alia,* for the manufacture of

1. Pharmaceutical and surgical rubber appliances
2. Rubber components used in contact with food
3. Infant items and toys

Due to its white colour and high solubility, latex crepe is widely used in the adhesive tape industry too.

Sole crepe is an improvement of thin lace crepe rubber to be used in the winter shoe industry; because, plantation sole crepe provides the best grip on icy surfaces. It is also best for the manufacture of soles for those who are sensitive to static electric currents generated between the ground surfaces and the shoe sole.

In addition to that, sole crepe is now becoming popular in the fashionable shoe industry around the world.

In the processing of rubber latex into latex crepe, latex is strained by multiple passes through sieves of different mesh sizes to remove extraneous dirt and micro-coagula prior to subsequent operations. Crepe rubber is manufactured using either fractionated or unfractionated latex. Very often the fractionated latex is bleached to obtain maximum clarity. The latex coagulum is washed thoroughly during creping to remove serum substances and dried under controlled conditions over a period of time lasting 3 - 4 days at a temperature of 34°C in drying towers. The light colour of latex crepe is a result of systematic and controlled production methods adopted in the processing factory and plantation. Emphasis is usually placed on yield per hectare when selecting clones for planting. Yet pale crepe producing estates must also look into the colour of the clonal latices to give the best results from crepe manufacture.

2. REQUIRED LATEX CHARACTERISTICS

Field latex to be used for the manufacture of pale crepe preferably should have the following characteristics:

- should be relatively free from yellow pigments – high content of yellow pigments in latex results in yellow discolouration in processed rubber.
- should not have a marked tendency to undergo enzymatic discolouration,
- should be free from amines or other compounds which cause darkening of the finished pale crepe known as storage discolouration.
- Should have reasonable hardness after processing into crepe form.

2.1 Yellow discolouration

Latex contains carotenoid type pigments which are yellowish in colour and this yellow pigmentation is usually a clonal characteristic. For crepe production the latex should preferably be predominantly white and hence latex should be obtained from clones that have lower percentages of yellow pigments. In the case of clones with yellow coloured latex, a higher percentage of fraction has to be removed in crepe manufacture.

When upward tapping starts in old trees, when trees are first opened up and the interruption of the normal tapping cycle often yields latex containing a higher percentage of yellow pigments. Increase of yellow pigments in latex could also be seen for about two weeks before or after the wintering period.

In practice, most of the yellow pigments in latex are removed with the yellow fraction during the fractionation process and the remaining pigments in the white fraction are bleached by means of a bleaching agent.

2.2 Enzymatic discolouration

This discolouration of rubber is due to the conversion of naturally occuring phenols and aminophenols into coloured compounds by enzymatic oxidation.

Enzymes of the polyphenoloxidase type catalyse the combination of phenols and aminophenols naturally present in the latex with oxygen from the air to give orthoquinones. These orthoquinones then react with naturally occuring amino acids and proteins present in latex, giving coloured compounds resembling melanin. Reduced melanin is tan in colour while oxidised melanin is black. The latex is coloured grey, brown, or black due to enzymatic discolouration.

The tendency for discolouration is also more pronounced in latex collected after few days rest, collected during rainy weather or from high tapping cuts. Intensive tapping and tapping just after yield stimulation too cause severe discolouration due to an enzymatic reaction.

When sodium bisulphite or sodium metabisulphite is added to the latex to prevent enzymatic reactions taking place in processed rubber usually appears as greyish in colour. This effect is minimised if sodium sulphite is used as an anticoagulant in the field since sodium sulphite too has a similar action to sodium bisulphite. It may be mentioned that the latex of clone PB 86 which has been a very popular clone in Sri Lanka, is not prone to discolouration. Bulking of latex obtained from clone PB 86, with that of latex from other clones susceptible to discolouration, prior to coagulation would minimize discolouration which would otherwise be observed if latex from other clones are coagulated separately.

2.3 Discolouration on storage

Compounds of the amine type, which occur naturally in the latex and are carried through to the final pale crepe, are said to react slowly with metal ions such as magnesium and calcium to give brown discolouration during storage. The use of oxalic acid as a coagulant or as a part of the coagulant prevents this type of discolouration. Use of purified water free of Ca^{2+} and Mg^{2+} ions eliminates the problem entirely.

2.4 Hardness of rubber

The hardness of rubbers prepared from different clones varies considerably. The harder the rubber, the more satisfactory it is for preparing pale crepe. At the same time a very hard rubber is not desirable from the consumer's point of view.

The variation in hardness is not necessarily due to difference in molecular weight because intrinsic viscosity and hence the average molecular weight of rubbers from different clonal and seedling sources are bound to be very similar. Difference in "hardness" may be due to differences in amounts of fats, resins, gel and naturally occurring reactive groups rather than to small differences in the basic rubber molecule. Gel content is relatively high during the first few tappings after opening. Subsequently it falls to a low level and is not normally subject to further variation. The gel moves into the first fraction during fractionation. The gel does not upset vulcanization, but can interfere with dissolution of rubber in a solvent. Another reason for the variation in hardness is the fact that crosslinking occurs naturally to a greater or lesser extent, depending on the number of reactive groups in the rubber molecule and on storage conditions.

3. FACTORY OPERATIONS

3.1 Bulking of latex

Field latex is collected in bulking tanks which are usually of rectangualr shape and their capacity should be more than the total volume of the highest daily crop that is anticipated and the volume of water to be added in the standardization process.

The depth of the tank should not be more than 1.2 m; otherwise a longer time would be taken for the sediment in the latex to settle to the bottom. The tank should not be too wide, preferably not be more than 1.8 m; otherwise a thorough mixing of latex to obtain a satisfactory homogenisation cannot be carried out efficiently. The tanks may be built out of brick, or concrete with inside and bottom lined with white glazed tiles (Plate 3.1a). Cement - lined tanks are also used, but they are liable to corrosion by acid water resulting in contamination of latex with impurities. The outlets should be fitted 2.5 cm above the bottom of each tank and they should be provided with detachable plugs which are usually made out of cork.

3.2 Prevention of enzymatic discolouration

When latex is bulked in bulking tanks, sodium bisulphite or sodium metabisulphite is added as early as possible as a freshly prepared solution to the latex to prevent enzymatic discolouration in the pale crepe rubber. Sodium metabisulphite is preferable to sodium bisulphite as it contains more sulphur dioxide as active ingredient. Sodium metabisulphite and sodium bisulphite should contain about 64% and 61.5% sulphur dioxide, respectively. However, sodium bisulphite can be used in place of sodium metabisulphite. The maximum quantity of sodium metabisulphite required is 500 g per 100 kg of dry rubber; but a lesser quantity may be sufficient depending on the quantity of the field latex. If oxalic acid is used instead of formic acid as the coagulant, the dosage of sodium metabisulphite could be reduced to almost half, as oxalic acid also inhibits enzymatic discolouration.

Sodium metabisulphite rapidly decomposes when exposed to air, particularly under tropical conditions, resulting in a decrease of the sulphur dioxide content and consequently a drop in activity. It is important that sodium metabisulphite used is of good quality. The use of poor quality sodium metabisulphite may cause brownish or greenish discolouration to appear on both bleached and unbleached crepe. If the chemical is found to have been deteriorated during inspection it should be discarded.

Sodium metabisulphite should be in powder form and if hard lumps are found, it indicates deterioration. The containers have to be kept tightly closed in a dry place and should not be left open unnecessarily.

3.3 Standardisation of latex

In order to maintain uniformity in the appearance and the quality of the prepared crepe, it is recommended that the latex be diluted to a standard dry rubber content. Standardization of latex is carried out while the latex still in bulking tanks. Mixing of chemicals into latex also becomes easy when latex is standardised, as it reduces the viscosity of latex. Where a fraction is not taken it is recommended that the latex be diluted to a standard dry rubber content (DRC) of 15%. When a fraction is taken, the level of DRC after standardisation varies depending on the method of fractionation. If the manual method using a paddle is employed for fractionation, the latex is first standardised to a DRC of 21.5%. Fraction formation is subsequently controlled with further dilution of latex to 15% DRC. If the aeration method is employed for fractionation, latex is diluted to a standard DRC of 15%. However in the manufacture of sole crepe rubber even further dilution of latex would be accepted to maintain better colour of the final production. Annex II could be used as a guide to calculate the amount of water required for standardization of field latex.

3.4 Fractionation of latex

Fractionation or partial coagulation consists of coagulating the latex in two stages and obtaining first the yellow fraction and then the white fraction. The normal procedure is to add sodium bisulphite to the latex, standardise the latex, allow the yellow fraction to coagulate without the use of any acid, and obtain as low a percentage as possible of the yellow fraction (about 10%). No definite rule can be laid down as the fractionation depends on the conditions on the estate such as the type of clone, the nature and amount of anticoagulant used, and the weather. The percentage of yellow fraction should not normally exceed 12%.

Two techniques could be employed for fractionation of rubber latex namely (i). Manual method using paddle
(ii). Aeration technique

3.4.1 Manual method for fractionation of latex

After standardization of the field latex to a DRC of 21.5% and the addition of sodium bisulphite, the latex should be stirred briskly for two 20 – minute periods with an interval of about 10 – 15 minutes midway. While stirring, it will be necessary to dip one's hand into the latex occasionally in order to ascertain whether the yellow particles are forming. If the particles of yellow rubber in the latex are visible on the palm of the hand, the latex is allowed to remain undisturbed for about 10 minutes and is then stirred gently until the yellow particles form into clots. But if at the end of the period of mixing particles of yellow rubber are not visible on the surface and on the palm of the hand, stirring should be continued for about another half an hour. The process is continued until the fraction is formed.

In practice, if it is found that the percentage of yellow fraction is high, further dilution to a DRC of 175-150 g per litre should be carried out immediately after the yellow particles appear. The formation of clots in such circumstances will take a little longer. Hence the latex will have to be stirred gently after standardization until such time as the yellow particles form into clots.

3.4.2 Aeration technique for fractionation of latex

Field latex is standardised to a standard DRC of 15% after the addition of sodium metabisulphite. Compressed air is passed through the latex for 10 minutes at 20 minute intervals by means of a set of perforated pipes immersed in the latex. Aeration of latex with compressed air agitates the latex briskly resulting in coagulation of less stable particles which have a higher percentage of yellow pigments. These coagulated particles emerge to the surface of the latex and could be removed with the froth formed during aeration. Aeration is continued at 20 minute intervals until no tiny coagulated particles appear with the froth formed during this agitation. This method gives the first fraction with the highest percentage of yellow pigments in it, and thereby reduces the loss of good rubber in the first fraction as would be experienced when employing the first method of fractionation, the manual method.

Coagulation of the residual latex, after taking a fraction and straining through a 60 mesh sieve, usually produces a pure white crepe. Removal of the fraction must not be delayed, or the white latex in it may be spoilt, resulting in a slightly streaky appearance in the finished product. If a bleaching agent is added into the white latex after straining through the 60 mesh sieve, then only the remaining carotenoids in the white fraction will be bleached. Fractional coagulation has the disadvantage that it is time consuming and it results in converting only part of the crop into first quality crepe. The fraction removed will be processed into latex crepe No. 4 or an off grade.

3.5 Latex in settling/coagulating tanks

After the process of fractionation the latex is allowed to flow into the settling/coagulation tanks through a 60 mesh strainer. These settling/coagulation tanks should be situated at a lower level to that of bulking tanks enabling latex from the bulking tanks to flow into them by gravity. Addition of bleaching agents to bleach the rubber and to coagulate the rubber prior to milling are carried out in these tanks.

These are usually masonry tanks lined with glazed porcelain tiles (Plate 3.1b). Aluminium or epikot resin coatings are also suitable for lining these tanks. Polypropylene or polyvinyl choloride sheet-lined tanks are unsuitable because of the adhesion of the coagulated rubber to the plastic sheeting, resulting in difficulty in cleaning the tank. Coagulating tanks can be conveniently constructed in units holding 2000 – 3000 litres of latex. Aluminium partitions positioned by means of a frame resting on the top of the tank may be provided to divide the coagulum into slabs of about 7.5 cm thickness. The depth of the tank should be such that the slabs of coagulum are of appropriate width to suit the grooved creping mills, e.g. if 65 cm mills are used, the width of the coagulum should be 57.5 – 60.0 cm. If the mills are only 37.5 cm wide, it is preferable to prepare slabs double the required width and to cut them before milling.

3.6 Bleaching with water-soluble rubber bleaching agent

Bleaching agents are added to latex in settling/coagulating tanks to bleach the carotenoid pigments, a naturally occurring material in rubber latex.

Oil-based tolyl mercaptan known as RRI–7 was the only rubber bleaching agent used in the crepe rubber industry before 1985. This has been modified to make it water soluble and free of the foul smell and this is commercially used now as a 35 – 40% aqueous solution marketed under four different trade names, viz. Nexobleach new formula, Rupepa, RPA- 4 and Polybleach. As it is water-soluble no emulsifier is needed for this new bleaching agent unlike for the previous oil-based tolyl mercaptan.

The stock solution is prepared as follows:

> 10 parts of water soluble sodium paratoluenethiophenate (35% solution) + 190 parts of water = 200 parts of stock solution (5%), or,
>
> If the oil soluble chemical is used for bleaching, 10 parts of the bleaching agent + 1 part of the surfactant mixed with 189 parts of water make the 5% emulsion.

About 2-3 litres (100 g – 150 g from 35% solution) of either of these solutions are required to bleach 100 kg of dry rubber to obtain the desired bleaching effect. Normally lower dosages are recommended for white and fractionated latex and the higher dosages for yellow and unfractionated latex.

For the manufacture of bleached crepe, two different methods have been used.

i. Bleaching without fractional coagulation. (UFB)
ii. Fractionation and then bleaching (FB).

Taking into account the different conditions prevalent in estates, the choice of the better method and the amount of bleaching agent to be used, have to be decided by each estate individually. In order to determine the process needed to follow, it is important to conduct small-scale trials. On the basis of the results obtained from these trials large-scale manufacture can be done.

The amount of tolyl mercaptan or its sodium salt required for bleaching is very small. The bleaching effect depends on the inherent properties of latex and on the method of bleaching, but the amount is generally 0.035- 0.05% of sodium salt of mercaptan calculated on dry rubber. Since the mercaptan has a tendency to react with the rubber molecule leading to chain break down which softens the rubber and increases tackiness, the upper limits shown above must not be exceeded. In most cases the amount required for a good bleaching effect will be much lower than the upper limit. On the basis of the above calculation about 0.120 kg of the 35% solution of mercaptan would be sufficient to bleach 100 kg of rubber and the estates could maintain adequate stocks of the bleaching agent based on this dosage. Keeping large stocks for over 3-6 months will give bad results as the shelf life of the bleaching agent is a maximum of 3-6 months.

3.6.1 Toxicity of water soluble mercaptan and handling precautions

Risks involved in handling of the water soluble bleaching agent are very much less than the oil based bleaching agent as the former is an aqueous solution and there is no vapour emanating from the dissolved chemical. However, contact with the skin should be avoided and workers who handle the bleaching agent should wash their hands thoroughly with soap and water immediately after the operation.

3.7 Coagulation of latex

After the addition of bleaching agent to latex, acids are added to coagulate the rubber in latex.

3.7.1 Coagulants

Formic acid is the best coagulant for coagulation of latex. However, under special circumstances, especially when the hardness of the water used for processing is high, coagulation with oxalic acid is recommended either partly or entirely in sole crepe manufacture. However, in Sri Lanka no estate use this material even for sole crepe manufacture.

3.7.1.1 Formic acid

Coagulation is achieved by the addition of formic acid at the rate of about 3.5-4.5 ml of 85% strong acid per kg of dry rubber. The acid is added as a 1% solution with brisk stirring. In order to obtain a 1% solution, one part of 85% formic acid is diluted with 84 parts of water.

3.7.1.2 Oxalic acid

The amount of oxalic acid required for coagulation is about 550 – 750 g per 100 kg dry rubber, added as a 2% solution. Sometimes this dosage may have to be increased, depending on the amount of anticoagulant present in the latex. As the crystalline oxalic acid is not very soluble in cold water, it should be dissolved first in 10 parts of warm water and then diluted with cold water to a concentration of 2%. Oxalic acid should not be dissolved in metallic containers but in glass jars or in plastic vessels. It should be handled carefully as it is corrosive to the skin.

It has been observed that an improvement in colour and colour holding properties can be obtained if oxalic acid is used in place of formic acid. The discolouration of crepe on storage caused by metal ions can be prevented by the use of oxalic acid as a coagulant or as part coagulant. Oxalic acid acts as an inhibitor of enzymatic action, and reduces the chance of discolouration. When oxalic acid is used as the coagulant, the dosage of sodium bisulphite or metabilsulphite could be reduced by half. There are indications that, at least in certain cases with white latex, removal of a first fraction might be unnecessary when oxalic acid is used. For estates having white latex it may be suggested that small-scale trials be carried out with oxalic acid, without removal of the first fraction. If the results are satisfactory, it could be used on a large scale. This would be an economic advantage if the percentage of latex harvested daily from young rubber areas and intensively tapped areas is very small and the price difference between No. IX and No. 1 grades is small.

3.7.2 Mixing coagulant and removal of froth

The latex should be thoroughly stirred for several minutes during and after the addition of the diluted acid. Since the retention of froth (which usually forms in latex due to stirring) will tend to cause streakiness of the processed crepe, it should be removed after mixing of acid into latex. After removal of froth, partitions may be placed in the tank at suitable intervals in order to break up the coagulum after complete coagulation.

3.8 Milling of rubber

After the latex is coagulated, coagulum from the coagulation/settling tanks is removed and processed into the following grades of rubber depending on the availability of machinery and according to customer requirements:

- Blanket crepe rubber
- Thin lace rubber
- Sole crepe rubber

Milling rollers such as macerator mills, diamond or spirally grooved mills and smooth mills are commonly used in Sri Lanka to manufacture the above grades. However, the number and the type of rollers required vary depending on the type of rubber to be manufactured (Plate 3.1c).

4. BLANKET CREPE MANUFACTURE

4.1 Machinery

The types of machinery required for the preparation of blanket crepe are:

- Horizontally grooved rollers for washing and breaking the coagulum (Plate 3.1d)
- Smooth rollers for preparing the thin lace (Plate 3.2a).
- Horizontally grooved rollers for blanketing: rollers used in Sri Lanka at present are usually 65 cm in width and 35 cm in diameter, with internal water cooling. But some smaller mills are still in use. Large machines are to be preferred as they are more economical in power consumption and labour requirements due to higher outputs.

The efficiency of crepe rollers varies according to the tendency of the wet rubber to slip and this tendency mainly depends on the surface texture of the rollers. The most suitable material for crepe rollers is hard, close-grained cast iron, which tends to roughen with use and grips the rubber well. Chilled iron tends to become smooth with use and increases the tendency to slip. The best output is obtained with cast iron rollers. Chilled iron is preferable for blanketing mills.

The rollers are adjusted by means of a large screw set at each side of the machine. In many modern machines the screws are of steel, and this material should be specified when ordering.

The machine should be set up a few centimeters above the general floor level of the factory. The area round the machines should be tiled with glazed tiles set in acid proof cement. The floor should slope slightly so that waste water flows towards suitably placed drains.

Machines should never be allowed to run without rubber between the rollers unless the rollers are well separated.

4.1.1 Grooving of rollers

Horizontal grooving is common in Sri Lanka. While probably less efficient than diamond grooving for breaking down the coagulum, it has the advantage of being easier to re-cut, and allows the machine to be used for blanketing if required.

The grooves should be approximately 3 mm wide and 3 mm deep and 12.5 mm apart. A groove of U section is preferable to a square cut or V groove.

4.1.2 Gear ratios

Most batteries have an increasing differential along the battery from washing rollers (macerators) to smooth (finishing) rollers. The gear ratio of the macerator may be at 18/21 whereas that of the finishing rollers are usually about 17/32. The underlying principle appears to be to roll out the coagulum gradually. It is claimed that a high differential on the macerator produces a lace material which has to be doubled at a later stage, causing unnecessary machining and resulting in a tough coarse rubber passing to the finishing rollers. A high differential is essential on finishing rollers if a close texture crepe is to be produced.

4.1.3 Washing rollers

If only one machine is used, a gear ratio of 18:21 is suitable. If two machines are used one should be geared 17:32 and used for breaking down the coagulum. The other should be geared 18:21 and used for final rolling. The quantity of water used for these mills is about 500 litres per hour.

4.1.4 Smooth rollers

A gear ratio of 17:32 is recommended for smooth rollers. This produces crepe of smoother texture than what is obtainable with even speed rollers. Water consumption of these mills is about 750 litres per hour.

4.1.5 Blanketing rollers

If a separate machine is reserved for blanketing, the rollers should be run at equal speeds.

4.1.6 Speed of rotation of rollers

For rollers of 35 cm diameter, the speed should not exceed 18 – 20 revolutions per minute (rpm) for wet rolling and 15 (rpm) for blanketing. These speeds refer to the faster moving roller. The smooth roller must run at a slow speed (around 13 rpm) to produce better lace with less perforations.

4.1.7 Care of machinery

Rollers should be thoroughly washed each day after use. It is also desirable to wipe the rollers with a cloth soaked in a dilute solution of washing soda (20 grams per litre of water), in order to remove any acid which remains. The rollers should then be thoroughly rinsed to remove all traces of soda solution, and dried as far as possible.

Grease or oil for bearings should not be used in excess, since contact with oil causes deterioration of the rubber. It would be preferable to use nylon bearings for smooth rollers.

Worn parts of machines should be replaced. Worn machinery produces rubber of inferior appearance.

4.2 Milling procedure for blanket crepe manufacture

4.2.1 Maceration

The coagulum should be divided into slices not exceeding 7.5 cm in thickness (preferably by the use of partitions in the coagulating tank, or by cutting to the required size). Five rollings in the grooved roller, under a good water spray, are sufficient to wash out serum substances and bring the rubber to a suitable form for passing through the smooth roller, provided the machine is in good mechanical condition. Four rollings may be sufficient if the first two are done in a mill with 17:32 gearing.

The output of the machine depends largely on the thickness of the milled rubber. The breadth after the final rolling should be such that the blanket can be fed into the smooth roller without tearing.

4.2.2 Smooth rolling

The rubber should be passed once through the smooth roller (Plate 3.2a). The smoothness of the finished crepe with minimum perforations depends partly on the texture of the roller surface, partly on the gear ratio, and partly on the speed of rotation of the machine.

The thickness of the crepe must be regulated according to the drying facilities available. For unassisted air-drying, a thickness corresponding to a weight of 600 g per sq meter (dry rubber) is suitable but it may be increased to 675 g per sq metre, where conditions are more favourable. For warm air drying, a thickness corresponding to 750 g per sq metre is satisfactory.

In order to obtain the maximum output from the machine, the full width of the rollers should be utilized. The hoppers should not overlap the edges of the rollers by more than 4 cm. If the rollers are worn, the full width cannot be utilized and hence it is economical to have them re-machined.

4.2.3 Blanketing

Preferably, a separate machine situated in the packing section of the factory should be reserved for blanketing. If one of the macerator rollers is used, it must be dried thoroughly before blanketing is started.

It would be necessary to have two well planed pieces of wood securely fitted to the two sides of the rollers to restrict the feeding width to approximately 52 cm. This in practice will result in a finished product of 55 cm in width. The reason for such a restricted feeding width is that while obtaining the correct width in the process of passing the laces through the mill, uniformity in width throughout the length of the rolled blanket is ensured.

Each estate will have to use its own system of preforming the crepe laces, before blanketing, to obtain straight edges. As a general guide the following procedure may be adopted:

i. Dry laces in mat form are spread on a low table after sorting for colour and dirt contamination. About seven of these mats are placed one over the other to overlap and folded to form a long strip of laces of three layers.
ii. The above preformed strips are passed through the blanketing mill once to get a resulting blanket of 2 – 2.5 cm thickness. These mats are allowed to cool for at least 5 hours, and then rolled a second time with the roller nip adjusted to get a final mat of 2 cm thickness of the finished product. It is essential that the rollers are efficiently and adequately water- cooled when blanketing is carried out.

4.2.4 Cutting of blanket crepe

The standard size of blanket crepe specified by the brokers is not more than 46 x 60 cm and not less than 44 × 55 cm. It is desirable that one standard size is always maintained between these limits. The method of cutting blanket crepe is as follows:

The blanket crepe is piled on a special table to a suitable height and cut by means of a cross cut saw, with the teeth removed, and the blade well sharpened.

An alternative method is to use a large knife, dipping the blade in a bucket of water frequently. Only two or three blankets can be cut at a time by this process.

5. Thin crepe and sole crepe manufacture

5.1 Machinery and milling

When manufacturing thin pale crepe or sole crepe, it is essential to have spiral or diamond-grooved mills in addition to grooved and smooth mills. The spirally grooved mill (Plate 3.1d) will produce a far superior wet blanket with a much more even texture and a minimum of perforations. With a close woven wet blanket the final lacing in the mills is made easier, resulting in a superior grade sole crepe lace or thin crepe lace, compared with a similar product that has not been milled through spirally grooved rollers. The approximate number of millings necessary for blanket crepe, thin crepe and sole crepe manufacture is given in Table 3.1. Generally, the macerator has heavy grooving, the intermediate machines a lighter grooving and the finishing machines are smooth. The grooves are often 2.5 mm wide (and deep) but may be as much as 4.0 mm wide, intermediate machines usually have grooves about 1.5 – 3 mm in width and gearing with a differential of 1:1.5.

Table 3.1. Approximate number of millings and gear ratios necessary for crepe manufacture

Type of mill	Type of roller Surface grooving	Process of manufacture and Number of mill passes			Gear ratio
		Blanket crepe	Thin pale crepe	Sole crepe	
Macerator	Horizontal	5	4	4	1:1.25
Diamond roller	Spiral	-	3	7	1:1.5
Smooth roller	Smooth	1	1	2	1:1.8
Blanket roller	Horizontal	2	-	-	1:1
Laminator	Smooth	-	2	2	1:1

5.2 Inspection and preparation of dried laces for lamination

After drying, the laces are wound on spindles (Plate 3.2b) and transferred to the laminating tables (Plate 3.3b) for inspection and removal of any specks of dirt and any other defects such as wrinkles and small holes. Lamination of sole crepe laces should be avoided under humid conditions as this may lead to “splitting”. Mould could also set in. To facilitate handling of laces, frames for supporting the spindles may be used at the starting end of each laminating table. The laminating tables have smooth wooden tops (Plate 3.3b). Their length should be in multiples of 90 cm which is the standard length of the finished product, with 30 cm in addition sometimes.

At both ends of the table four galvanized iron spikes, two at each end, are firmly fixed at the edge. It is to these spikes that the sole crepe laces are fixed into position. Two lengths of the laces are spread on the table and the corners fastened on to the spikes without undue stretching.

Each lace is examined for dirt particles which are removed by cutting with a pair of scissors, lengthwise (Plate 3.3c). Thereafter each lace is built up one over the other to the required thickness to obtain the finished product following the above procedure. Finally a hand laminator is rolled over the stack of laces to keep the lamination intact.

5.3 Lamination

The hand-laminated sole crepe is now passed through a power driven laminator (Plate 3.3d). There are two types of laminating mills: the larger 55 cm × 30 cm mills can press the rubber more efficiently but are more expensive; the smaller 60 cm × 15 cm laminators are also used satisfactorily. If corrugated sole crepe is to be manufactured, a separate mill is required in which one of the rollers is horizontally grooved. The speed of the rollers of the laminator should be even and should be 10 – 12 rpm. It is important to ensure that the pressure applied is adequate: if not, it would be possible to separate the plies at a corner of the sheet with a fine nail, and the consignment will be heavily penalized when tendered for auction. The usual remark by brokers to indicate this defect is "splitting". On the other hand, too much pressure will cause "ruts" on the surface and will give the finished sole crepe an uneven appearance. The output rates of laminating mills will depend on the thickness of the sole crepe manufactured. The relationship between the thickness and the output rate for two rollings is approximately as follows, for laminating mills 55 cm × 30 cm, working at 12 rpm:

Thickness		Output	
9 mm	3/8"	460 lb/hour	200 kg/hour
8 mm	5/16"	355 lb/hour	175 kg/hour
6 mm	¼"	310 lb/hour	140 kg/hour
4.5 mm	3/16"	220 lb/hour	100 kg/hour
4 mm	5/32"	200 lb/hour	90 kg/hour
3 mm	1/8"	150 lb/hour	70kg/hour

The thickness is finally checked with a pair of calipers after cutting the edges using a template. The cut edges are reprocessed into sole crepe or blanket crepe.

6. DRYING OF CREPE LACES

Crepe rubber in the form of laces is dried either in natural air or warm air. Warm air drying is essential for quality latex crepe manufacture.

The drying of sole crepe laces is similar to that of pale crepe laces except that in the case of sole crepe laces, warm air-drying is carried out and usually single laces are hung for drying instead of mats. For both latex crepe No. IX grade and sole crepe, natural air-drying of laces in a loft is not permitted.

6.1 Drying characteristics of crepe rubber

The initial moisture content of the crepe laces after final smooth milling lies in the range of 12 - 20%. The drying of laces takes place in two stages:

(1). Constant rate period
(2). Falling rate period

During the constant rate period the moisture level drops to about 3% and in the falling rate period further drops from 3% to an average moisture content of less than 0.5%. The falling rate period occupies about 85% of the total drying time. The variation of moisture level in rubber laces during drying at 34°C is shown in Fig.3.1.

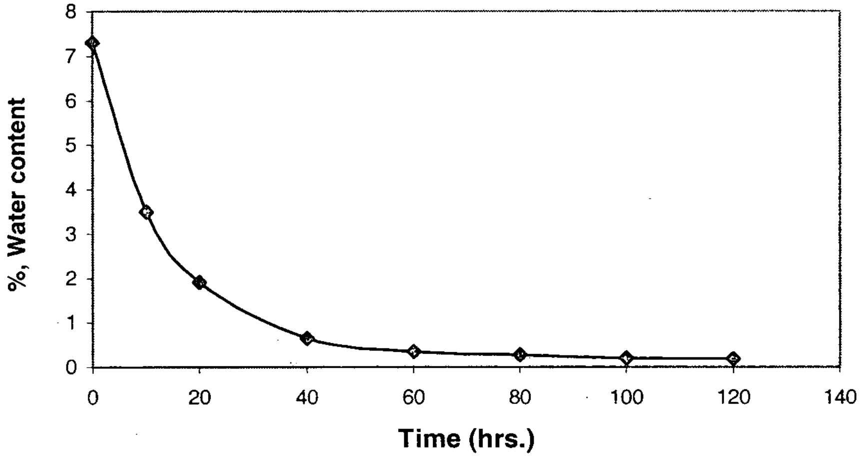

Fig. 3.1. Variation of moisture level of crepe laces during drying at 34°C

6.2 Drying systems for crepe rubber

The drying systems for crepe rubber can be categorised into 4 types:

(i). Loft drying - Natural air drying
(ii). Warm air drying in conventional drying towers
(iii). Forced air drying
(iv). Vacuum drying

6.2.1 Natural air drying

Natural air drying of crepe rubber could be done in the loft with no difficulty in fine weather. Laces of average thickness (dry weight of 600 g per m^2) usually dry in 4 to 6 days. But in wet weather, drying slows down and as a result, surface mould is liable to develop on the rubber, leading to a product of dull or mottled appearance. In extreme cases the mould spores can be seen as a cloud of dust when the crepe is shaken. Contamination of the surface of crepe rubber with mould is particularly liable to occur in Sri Lanka owing to high relative humidity and the long wet seasons in the main rubber growing districts. It is not uncommon to see fungal spots of various colours developing on the rubber when drying is slow. Furthermore, for the manufacture of latex crepe No. IX, loft drying is not recommended.

Crepe should not be considered dry until all "virgin" spots have disappeared. Small moisture spots dry out to a certain extent during the blanketing process, but there is a danger that they may remain and cause fungal spots to develop in the rubber after packing. The dry crepe should be taken out in the afternoon from the drying tower and made ready for blanketing on the following day. The moisture content of the crepe is then lower than it is in the early morning.

As a preventive measure against growth of microorganisms in the drying loft, the entire loft including all the wooden constructions, walls and floor should be sprayed with a 1% solution of formalin (commercial liquid formalin has about 38% formaldehyde). The factory floor and utensils should be disinfected periodically, once or twice a week.

6.2.2 Warm air drying in conventional drying towers

Most commonly, warm air drying of crepe rubber is done in a drying tower (Plate 3.2c), which is a multi-storey building warmed by a boiler-radiator system (Plate 3.2d). The source of heat is a slow combustion fuel stove. The number of radiators and their capacity will depend on the weight of the rubber handled by the drying house. Ventilation of the building is by natural upward draft. No electrical power is required and the requisite temperature can be maintained day and night.

The temperature of the building is kept at about 34 °C. Crepe laces of recommended thickness can be dried in 3 days, almost irrespective of the prevailing weather conditions, provided that the correct temperature and air flow are maintained in the drying house. The product has the characteristics of natural air-dried crepe.

6.2.2.1 Drying operation

Crepe laces are hung in the drying house (Plate 3.3a) in the form of "mats' (1.8 m long and 0.9 m wide) which are made by wrapping the wet crepe on to a rotating drum (Plate 3.2a) of the squirrel cage type (90 cm wide and 65 cm diameter) as it leaves the smooth creping mill. The plies of crepe are wrapped so that they half overlap and a mat of the required size is formed when the plies are cut across. The thickness of the crepe is such that 1 sq metre of dry crepe weighs 650 – 700 g, i.e. somewhat thicker than average. A mat of these dimensions weighs approximately 2.75 kg (dry weight). It has been found that mats dry at least as quickly as single plies. This is because the mats occupy less room than single plies and can therefore be more widely spaced, or raised higher from the floor to allow better air circulation. Hanging in the form of mats also reduces labour costs incurred in handling. However, in sole crepe manufacture it is preferable to dry single laces separately rather than in mat form.

The crepe mats are hung in the drying house on loose reepers which rest on bearers provided with notches to regulate the spacing (Plate 3.3.a). The most convenient procedure to adopt in hanging crepe laces is to start with all the reepers detached and then replace them one by one as the laces are placed in position.

If the full capacity of the drying house is not being utilized owing to a shortfall in crop, it will be found more satisfactory to hang the crepe at a wider spacing than to leave some of the bays unoccupied. This will tend to equalise the draft through the building.

Efficient drying in the specified period of 3 days can only be expected if the temperature is maintained at a uniform level of 34 °C. This can be ensured by providing a recording thermometer, which should be regarded as an essential part of the equipment of the drying house.

Once the boiler is fired, the water boils and hot water circulates through pipes by thermosiphon action from the top of the boiler to the top of the radiators and the water is returned to the boiler by means of another set of pipes at a lower level. Good heat transfer from the radiator surfaces to the air will ensure the efficiency of the system. Therefore, it is important that the radiator surface is always kept clean. The temperature inside the drying tower is maintained at 34^{0}C (93 ^{0}F). Adjustable vents right at the top of the tower offer some control over this temperature. While warm air is being convected up in the drying room and subsequently going out through upper vents with moisture released from rubber, ambient cold air is drawn in through the lower vents. The correct number of vents should be provided in the radiator room for optimum flow of air into the drying tower. The top ventilator should be kept fully open during the first 3-4 hours of drying to carry away the bulk of the moisture released to the drying room at the initial stage of drying. Thereafter it must be kept partially open, while regulating the airflow through the drying chamber to maintain the correct temperature.

6.2.2.2 Boiler and radiator

The majority of the boilers and radiators in most of the commonly used boiler-radiator systems are imported to this country. Several locally fabricated boilers and radiators are now in commercial operation in some of the crepe rubber drying towers. All these boilers are of wood-fired type. The number of radiators and the capacity of the boiler are determined by the capacity of the drying tower. The boiler rating of a 4100 kg capacity drying tower is 22 kW which is equivalent to 75,000 BTU/hour.

6.2.3 Forced air drying

An improved drying system has been developed by modifying the conventional boiler-radiator system. This system employs forced convection for circulating hot water from the boiler through small radiators by using a pump, whereas in the conventional boiler-radiator system hot water is circulated by natural convection (thermosiphon effect).

Another important feature in the new system is that the hot air is blown into the drying tower through a duct system via radiators. The radiators and air blowers are positioned just outside the drying tower and only air ducts are positioned inside the drying tower, close to the ground. This system therefore replaces small radiators housed on the ground floor in conventional type drying towers with one or two large radiators which are kept outside and hence space in the radiator room can be utilized for drying of laces and thereby drying tower capacity would be increased by about 33%.

In addition to the above modifications the drying tower can be vertically partitioned into 3 chambers into which hot air can be blown separately. This arrangement provides an additional advantage of supplying hot air only into the required chambers by opening only air vents (apertures) in the duct belonging to those particular chambers and closing the others. The definite advantages by partitioning the drying tower include:

i. Uniform and controlled air flow throughout the drying tower resulting in controlled drying rates and improved product quality
ii. Better scheduling of drying tower throughputs due to controlled drying rates.
iii. Improved continuity of production as one chamber of the drying tower would be in drying operation while another is being loaded or unloaded
iv. Improved drying efficiency during periods of low production.

As the drying operation is continuous, drying of laces can be accomplished in 1½-2 days, thereby further increasing the daily factory capacity.

6.2.4 Vacuum air drying

The drying of laces is carried out in a fully sealed container-like drying chamber. A partial vacuum is created by the suction of air from the chamber. Hot air is allowed to enter into the chamber at the bottom through a series of tubes, while the suction is being carried out. The size of the drying room once again depends on the daily crop. The drying time is reduced to 12 - 16 hours in this drying system. The operation of this type of a system is easier and less labour is involved, so it is considered to be a more efficient drying system. However, this system is not in operation anywhere in Sri Lanka currently due to the drawback of lowering of PRI of dried crepe rubber as evident from pilot plant studies.

7. GRADES OF CREPE RUBBER, SPECIFICATIONS AND APPLICATIONS

Though pale crepe is sold on visual grading according to certain criteria as given in the Green Book, there may be additional requirements which the consumer may desire, e.g. for preparing rubber solutions, pale crepe with low gel content, low oxidisability and high viscosity. Hence producers of pale crepe may have to adjust their manufacturing process to meet such requirements.

Average fractionated bleached crepe rubber could easily be produced under hygienic and carefully controlled conditions to conform to the specifications given in Table 3.2.

Table 3.2. Average raw rubber specifications for crepe rubber

Property	Specifications
Dirt content% (w/w)	0.020 (max.)
Volatile matter content% (w/w)	0.5 (max.)
Ash content% (w/w)	0.20 (max.)
Initial plasticity number (Wallace units)	30 (min.)
Plasticity Retention Index (PRI)	60 (min.)
Nitrogen content% (w/w)	0.35 (max.)
Mooney viscosity ML 1 + 4 @ 100 °C	75 – 85
Lovibond colour	1.5 (max.)

Depending on the method of manufacture, different grades of rubber are manufactured to suit end user applications:

7.1 Latex crepe - Food and pharmaceutical grade (SLCR-FP)

SLCR-FP is produced by removing the majority of natural proteins as the yellow fraction and also without using bleaching agents. No latex stabilizers except sodium sulphite is allowed for latex preservation. The colour of the end product may be greyish or off - white and will contain minimal foreign matter content and leachable protein compared to any other conventional grade of NR. Products made out of this grade of rubber do not cause allergies when used in contact with human tissues unlike products made out of any other grade of NR. It is ideal for the manufacture of catheter tubes, blood tubing and other surgical rubber appliances, baby toys, infant teething rings and rubber appliances used in contact with food.

Average properties

% Dirt content	< 0.02
% Volatile Matter	< 0.6
% Nitrogen content	< 0.35
Plasticity Retention Index (PRI)	> 60
Wallace Plasticity (P_0)	> 30

7.2 Latex crepe - Adhesive grade (SLCR –AD)

SLCR –AD grade is essentially be pure water white in colour. It is made by fractionation and bleaching, so that the resulting crepe rubber can be dissolved easily without gel formation. It is free of toxins too. Presented in thin lace form for easy dissolution in solvents used for the manufacture of adhesive tapes, gums and glues, sticky pads and also for making rubber derivatives like chlorinated rubber.

Average properties

%Dirt content	< 0.03
%Volatile Matter	< 0.6
%Nitrogen content	< 0.35
Plasticity Retention Index (PRI)	> 60
Wallace Plasticity (P_0)	> 30
Lovibond colour	< 3.0
Gel formation on dissolution	minimal

7.3 Latex crepe – General purpose grade (SLCR-GP)

This grade is similar to ordinary grades of latex crepe made from fraction removed or unfractioned, and bleached latex. Pure white in colour. Ideal for white shoe soles and for bright - coloured end products.

Average properties

%Dirt content	< 0.03
%Volatile Matter	< 0.6
% Nitrogen	< 0.45
Plasticity Retention Index (PRI)	> 60
Wallace Plasticity (P_0)	> 30
Lovibond Colour	< 3.0

7.4 Latex crepe - Low nitrogen grade (SLCR-LN)

Made by enzyme coagulation. Nitrogen and ash levels are below 0.1%. off white or Greyish in colour. Absorption of water to this rubber is minimal and hence ideal for making rubber components like water seals. Due to the high resilience it is specially recommended for dynamic rubber products aircraft tyres and bridge bearings.

Average properties

%Dirt content	< 0.03
%Volatile Matter	< 0.60
% Nitrogen content	< 0.10
% Ash	< 0.10
Plasticity Retention Index (PRI)	> 60
Wallace Plasticity (P_0)	> 30
Colour	Greyish brown

7.5 Latex crepe – Yellow Fraction grade (SLRC-YF)

This grade is yellowish brown in colour. It is not suitable for solution process products as it cannot be dissolved completely in solvents. It can be used for making very hard vulcanized surfaces such as rice huller roller surfaces and earthquake protectors.

Average properties

%Dirt content	< 0.05
%Volatile Matter	< 0.50
% Nitrogen	< 0.06
Plasticity Retention Index	> 60
Wallace Plasticity (P_0)	> 30
Colour	yellowish

All the above grades of rubber could be made available in compact 33.3 kg bales wrapped in polythene and exported along with a technical specification certificate issued by the Rubber Research Institute of Sri Lanka. This certificate will cover % dirt level, % ash level, % volatile matter (VM) content, Po, PRI, % N level etc. In the case of the Food and Pharmaceutical Grade, the certificate will also certify that the rubber is free of leachable chemicals.

7.6 Lankaprene

A new form of premium quality crepe rubber of extreme purity specially made for pharmaceutical, infant and food applications to replace synthetic cis-poly isoprene has been introduced by the rubber plantation companies in Sri Lanka supported by the Sri Lanka Rubber Cluster.

This grade of rubber has the typical raw rubber specifications given in Table 3.3.

Table 3.3. Typical raw rubber specifications for Lankaprene

Property	**Specification**
Dirt content% (w/w)	0.018 (max.)
Volatile matter content% (w/w)	0.40 (max.)
Ash content% (w/w)	0.25 (max.)
Initial plasticity number (Wallace units)	35-50
Plasticity Retention Index (PRI)	70-85
Nitrogen content% (w/w)	0.35 (max.)
Mooney viscosity ML 1 + 4 @ 100 °C	70 – 80
Lovibond colour	1-1.5 (max.)
Specific gravity	0.90
Onset of Tg °C	(-)70

The major advantage of this grade of crepe rubber is that it does not contain measurable amount of leachable proteins. Since this rubber is not heated to high temperatures during drying, there is no knuckle formation in the rubber.

Lankaprene manufactured from pressed thin lace is packed according to customer needs and normal methods are as follows;

- 25Kg bundles of size 17"× 23" × 6 ½"
- 35Kg bundles of size 17" × 23" × 8"
- Bundles are wrapped in LDPE film of guage 300
- TSR type 35Kg bales 26"×13" shrink wrapped and palletized
- Bales are floor loaded (17MT) or palletized (16MT) in 20ft containers.

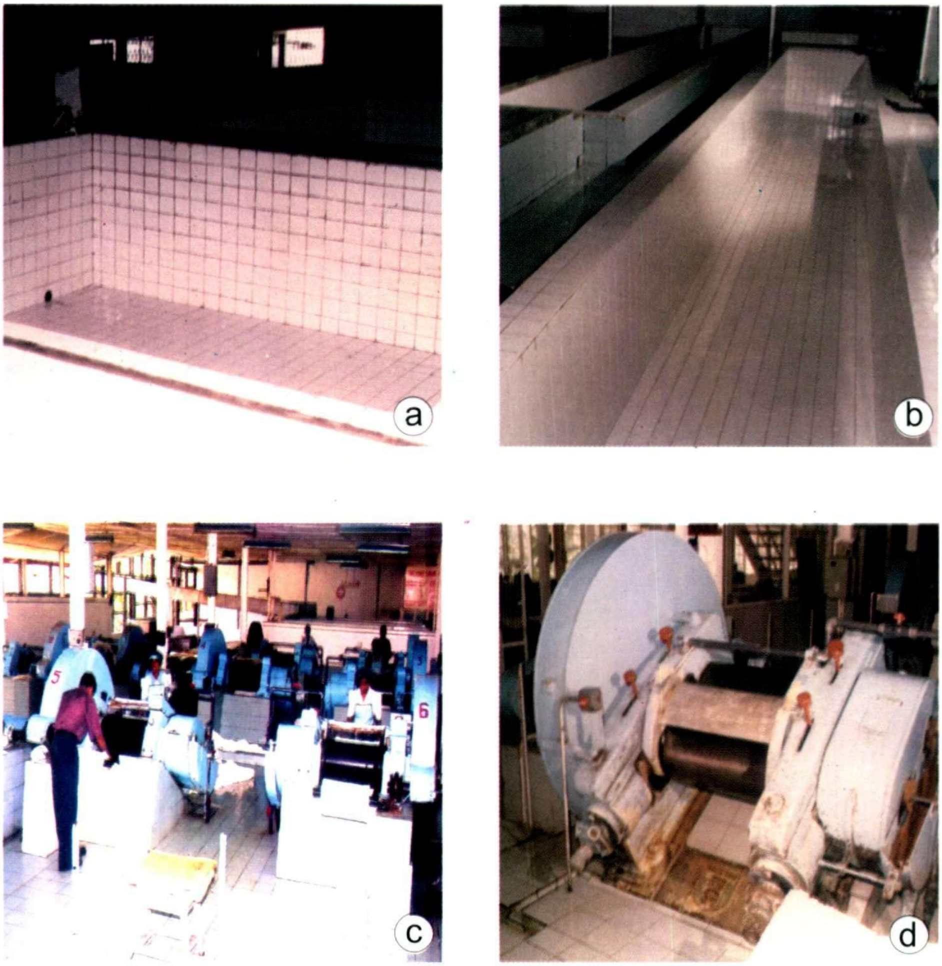

Plate 3.1. Tanks used for bulking and coagulation of latex and machinery used for rolling of crepe rubber. **a** Glazed tiled bulking tank; **b** Glazed tiled settling tanks; **c** Machinery layout in a rubber factory; **d** Grooved mills used for milling and washing of rubber.

Plate 3.2. Preparation of laces and drying of crepe. **a** Preparation of laces by passing rubber through a smooth mill and winding on a drum; **b** Laces wound on spindles ready for sending to the drying tower; **c** Exterior view of a drying tower; **d** Radiators housed on the ground floor of the drying tower.

Plate 3.3. Final stages of sole crepe and pale crepe production. **a** Laces hung inside the drying tower; **b** Inspection of laces **c** Examination and removal of dirt during preparation of laces for blanketing and laminating; **d** Lamination of laces for sole crepe.

Chapter 4

Brown crepe*

W.M.G. Seneviratne and P.H. Sarath Kumara

1. Introduction
2. Collection of field grades
3. Sorting and preliminary treatment of field grades
4. Creping machines and operations

1. INTRODUCTION

Brown crepe or scrap crepe known as FAB (Fair Average Brown) grades are made from rubber pre-coagulated in the field, i.e. cup lumps, tree laces (curly scrap), shell scrap and earth scrap. Cup lumps are obtained mainly from late dripping trees, but clones commonly grown in Sri Lanka are not late drippers. Therefore the cup lumps are characteristically small in size. They can be classified as shell scrap which is the thin strip of rubber formed on the shell from the latex that is left over in the cup during collection. Further, early collection of latex yield stimulation and onset of tapping panel dryness also result in late dripping and hence shell scrap and the grades of pre-coagulated rubber derived from the field constitute about 10 to 15% of the total crop and are either processed into brown crepes or technically specified block rubber.

Earth scrap is a relatively low grade of rubber. Latex which has overflowed from the tapping cut or latex collecting cup owing to rain or other causes, gets coagulated on the bark or on the ground at the foot of the tree. It will be soft and tacky having been exposed to the sun. It should therefore be collected at frequent intervals and any mud and sand washed off before processing. In view of the very high percentage of impurities in this rubber, it is not advisable to do any milling with it using soft or cast iron rollers.

It has been found that scrap available in Sri Lanka has defects such as high bark content, high volatile matter content and lacks consistency in quality. Therefore, the quality of scrap rubber grades mainly depends on the method of manufacture. Depending on the quality of scrap rubber as determined by visual appearance and the content of dirt, they are categorized into the following grades after processing.

1. Scrap crepe 1X Brown (FAB +)
2. Scrap crepe 2X Brown (FAB +)
3. Scrap crepe 3X Brown (FAB -)
4. Scrap crepe 4 (MCB)
5. Flat bark crepe 1X Brown (FB)

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* Adapted from "A Handbook of Rubber Culture and Processing", 1983

(FAB - Fair Average brown, MBC- Medium Brown crepe)

Dirt content should be as low as possible for these FAB grades to be converted into TSR (Technically Specified Grades). When producing TSR 20 grade it is customary that scrap grades are blended with high quality rubber such as RSS.

2. COLLECTION OF FIELD COAGULA

The tappers, before they commence tapping, remove the tree laces and shell scrap and collect them separately in small buckets or gunnysacks. Earth scrap is normally not removed by the tapper during tapping, but a special gang of labourers is entrusted with this job as the earth scrap should not contaminate the rest of the field coagula. Very often scrap material is left on the bare ground and this leads to contamination with sand and grit. This can be prevented to a large extent with adequate control measures in the field collection techniques.

3. SORTING AND PRELIMINARY TREATMENT OF FIELD COAGULA

The shell scrap material is sorted at the factory and the light coloured cup lumps are separated from the rest and processed separately into high quality brown crepe. Darkening of cup lumps due to enzymatic discolouration could be prevented or reduced by soaking in a solution of sodium bisulphite.

Preliminary milling of field coagula should be carried out in the type of machine known as a scrap washer. This may consist of deeply grooved mills rotating under water or else of a single roller with pointed projections, which force the rubber against similar projections, or ridges, on the casing of the machine. Scrap washers in use in Sri Lanka have an output of 20 – 35 kg per hour and the power consumption is approximately 12 HP. The rubber emerges from the scrap washer in the form of irregular "sausages" which are converted to crepe in the normally grooved and smooth mills.

4. CREPING MACHINES AND OPERATIONS

The number of passes through the macerator and the smooth roller when no scrap washer is used depends on the nature of the material to be processed. Normally when no scrap washer is used, 10 – 15 passes through the macerator and 3 – 5 passes through the smooth mill would be necessary. A sufficient quantity of water should be used to wash the rubber as it is being milled in order to remove as much dirt as possible. The quantity of water required is about 10 litres per kg of rubber. Power consumption in milling field coagula is considerably higher than that required for making pale crepe. Wear and tear of machinery is also high owing to the grit in the rubber and the large number of passes required.

Chapter 5

Technically specified rubber[*]

L. Karunanayake

1. INTRODUCTION

Prior to the Second World War, natural rubber (NR) was marketed mainly in the form of RSS and as different types of crepes. These rubbers were graded according to the visual grading systems laid out in the Green Book, and the following problems were experienced by the consumers of the visually graded rubbers:

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[*] Adapted from "A Handbook of Rubber Culture and Processing", 1983

(a) Poor methods of presentation in bare back bales, leading to contamination during transit and causing higher handling charges to the consumers.

(b) Non-uniformity in quality within a particular grade and multiplicity of grades, causing problems in product manufacture.

(c) Non-availability of technical information on the physical properties of the rubber.

In spite of these drawbacks NR could be successfully marketed in the conventional form due to its monopolistic position as the only rubber in the market. After the advent and rapid growth of the synthetic rubber industry, rubber products manufacturers changed their priorities with regard to their raw rubber requirements. Rubber manufacturers became more concerned with the need to reduce unnecessary handling and processing steps in the face of increasing labour and power costs, and consequently insisted on raw rubbers of greater consistency to eliminate or reduce the rejects in their increasingly automated plants. NR in its conventional forms required excessive handling and a number of extra steps such as precleaning, thawing, cutting of large bales and pre-mastication. An improvement in the way of presentation was therefore necessary to cater to the changing requirements of the consumer. The need was for a concept and a scheme which would meet the increasingly expanding demand of the consumer and also offer NR as a technically graded and a quality guaranteed product. Hence, technically specified rubber in block form was introduced which has the following advantageous features over conventional grades:

Improved methods of presentation in polythene-wrapped bales of easy-to-handle size; guaranteed limits for contaminants and certain basic raw rubber properties; consistency in technical properties; better and closer adaptation to consumer needs and production of speciality rubbers for particular purposes.

The assured quality of Technically Specified Rubber (TSR) together with its advantages in handling, storage and processing has led to its ready acceptance by the manufacturing industry. With supplies becoming more readily available, more factories are converting to almost exclusive use of this type of rubber wherever possible. Such conversion exploits the full potential of TSR in increasing productivity and streamlining production methods.

Further advantages of this TSR process to the consumer is that minor adjustments could be done in the process to slightly modify the product to fulfil special requirements of the consumers. One such modification is to stabilize the viscosity of the raw rubber by means of suitable chemicals so that storage hardening could be completely eliminated. This reduces the cost of manufacture of rubber products by cutting down on the energy consumption in the processing cycles.

However, in the light of increasing demand for scrap grades of rubber in the Sri Lankan market and due to fast increasing fuel and electricity costs, COM of the TSR rubber is very high compared to RSS and Crepe rubbers and hence the production of TSR in Sri Lanka is very small.

1.1 The technical specification scheme

Malaysia in 1965 launched the Standard Malaysian Rubber (SMR) scheme for their NR. Subsequently the other major NR producing countries launched schemes similar to SMR. In 1966 the Rubber Research Institute of Sri Lanka, in collaboration with the Sri Lanka Standards Institution, formulated specifications of raw NR-Technically Specified Rubber (TSR) and encouraged TSR manufacture in Sri Lanka, giving incentives and duty concessions. Thus for the first time in the history of the rubber industry in Sri Lanka, the system of grading of NR on the basis of technical parameters came into operation.

However, in Sri Lanka the manufacture of TSR has not been quite successful due to the following reasons:

i. Availability of a premium market for latex crepe rubber and therefore no latex grades, viz. SLR L, SLR 5L and SLR 5WF, are manufactured. But lower grades of TSR are being manufactured out of scrap rubber.
ii. Very high capital investment required to set up TSR factories.
iii. Higher electricity tariffs compared to other countries in the region and high fuel prizes make the cost of production of TSR higher.
v. The demand for lower grades of raw rubber created by the rubber based industries in Sri Lanka makes the local price of scrap rubber artificially high and hence conversion of scrap bought at high prices into TSR grades selling at prices parallel to RSS, makes TSR production non-viable in Sri Lanka.
vi. In order to make profits from the TSR process, a minimum of 5 MT should be produced in a factory per shift. It is not possible to collect raw material viz. scrap of that magnitude from the limited rubber production in the country.

1.2 Specifications for grading of raw natural rubber

The important parameters included in the original technical specifications scheme of the International Organization for Standardisation (ISO) were dirt, volatile matter, ash, nitrogen, copper and manganese contents. In 1970, the TSR scheme was revised with the inclusion of the Plasticity Retention Index (PRI), instead of copper and manganese.

Sri Lanka introduced the technical specifications scheme known as the Standard Lanka Rubber (SLR) scheme in 1966. After several revisions of the scheme, the prevailing specification limits determining grades of NR are given in Table 5.1. SLR 5L, SLR L and SLR 5WF grades are derived from deliberately coagulated latex, whereas SLR 5 (RSS) grade is restricted to sheet material. SLR 10, 20 and 50 grades could be manufactured from field grade material such as raw cup lumps and tree laces, brown crepe, off-grades of crepe, lower grades of sheet material etc. or their blends. Direct pressing of latex crepe 1X into SLR L (LC) is also permitted by the scheme.

Skim rubber should not be added even in small quantities in the manufacture of SLR.

Table 5.1. The SLR scheme

Types	SLR grade	Dirt (%wt) max.	Ash (%wt) max.	Nitrogen (%wt) max		Volatile matter (%wt)		Initial wallace plasticity min.	Plasticity index consumer min.	Retention (PRI) producer min.	Lovibond colour index max.
				Consumer max.	Producer max.	Consumer max.	Producer max				
Latex crepe	*L (LC)	0.03	0.50	0.60	0.55	0.80	0.70	30	60	70	3.0
Latex	L	0.03	0.50	0.60	0.55	1.00	0.50	30	60	70	6.0
	5L	0.05	0.50	0.60	0.55	1.00	0.50	30	60	70	6.0
	5WF	0.05	0.50	0.60	0.55	1.00	0.50	30	60	70	-
Sheet material by: a. comminuted process	5	0.05	0.60	0.60	0.55	0.80	0.70	30	60	70	-
b. pressed process	5(RSS)	0.05	0.60	0.60	0.55	0.80	0.70	30	60	70	-
Field grade material	10	0.10	0.75	0.60	0.55	0.80	0.50	30	50	60	-
	20	0.20	1.00	0.60	0.55	0.80	0.50	30	40	50	-
	50	0.50	1.50	0.60	0.55	0.80	0.50	30	30	40	-

*Made from fraction removed latex

1.3 Production of technically specified rubber

The production of TSR involves a series of unit operations which may vary slightly, depending upon whether field latex or field coagula is used as the feed-stock. Where field latex is used as the feed–stock, processing operations involve such steps as bulking, coagulation, dewatering, size reduction, drying, baling and palletising. In addition, regular attention is required at various stages of cleaning and blending.

The efficiency of drying of any material is largely dependent on the surface area of the material exposed to the drying medium. Hence particular forms such as crumbs will be more efficiently dried than a film or crepe. To take advantage of this, it is essential to achieve good size reduction, using suitable methods. Therefore, size reduction is the key operation of the TSR manufacturing process. This is achieved by the process called Mechanical Comminution.

In this process, for quick drying the rubber is converted into small particles or granules by mechanical actions such as cutting, shearing and tearing. In such operations, machines such as granulators, hammer-mills or extruders may be used.

2. MACHINERY USED FOR TSR MANUFACTURE

NR processing machinery has changed a great deal since the introduction of technically specified rubber. During the early stages, machinery then in use and machinery initially devised for comminuted or *Hevea* crumb processing have been utilised for the manufacture of all types of rubber, mainly as an interim measure and to reduce the initial capital cost. However as the output of TSR increased several fold, the industry has started using more sophisticated methods for production.

Prior to maceration hard bales of raw rubber are reduced in size by using a guillotine-type bale cutter.

2.1 Crepers/macerators

These machines consist of a pair of cast iron rolls, mounted on a grid framework, and rotated in opposite directions with or without friction ratio between them (i.e. even speed or uneven speed). A close gap between the rollers is always maintained by providing a holding screw to keep the bearing boxes in a desired position and by using a close tolerance between the bearings and the roll shaft. The roll surfaces are mainly cut with various-patterns of grooves to increase the grip of the feed material and to effect squeezing and shearing actions. During operation, these machines shear the feed rubber and spread it through the width of the roll. Due to natural tackiness, the feed rubber which leaves the crepe rolls forms into a continuous or semi continuous ribbon, i.e. crepe with evenly reduced thickness. With a liberal usage of water at the roll nip, a large amount of dirt is also separated from the feed material and washed out along with the waste water discharge.

Thus the main function of this machine is to remove the dirt and to reduce the thickness of the final rubber crepe by shearing the feed material which later greatly improves the drying characteristics of the rubber.

A macerator (Plate 3.1c) is a heavy duty creper with deep grooves for handling lumpy materials. The rolls of the macerator are normally mounted on journal (bush) bearings and the speed of rotation is equal to or more than 35 rpm.

These bearings rest on two solid iron frames with holding screws and safety blocks for roll nip adjustment and roll safety respectively. The rolls are driven by a common drive with an electric motor. The horsepower rating of the motor depends on the nature and the size of feed material and the output requirements and it ranges from 20-50 HP.

Some factors such as type and size of rolls, speed and speed ratios and groove patterns influencing the performance and throughput of crepers, are briefly summarized below:

- Slow roll of the creper consumes negligible power, leaving the fast roll to take most of the electrical work load.
- Increasing the fast roll speed at a given friction ratio increases the throughput and electrical load, but not proportionately.
- Roll friction ratios above 1:1.5 do not improve performance.
- Increasing the feeding width increases the throughput of the creper but not proportionately.

2.2 Latex coagulum crusher

A coagulum crusher consists of a pair of grooved heavy duty rolls resembling the conventional scrap washer roll and its principle of operation is similar to that of a creper. However, in order to avoid breaking off the coagulum at the nip, no friction ratio is applied between rolls.

During operation, coagulum blocks are fed into the nip between rolls and crushed to form a continuous ribbon of coagulum. Thickness of the crushed coagulum is dependent on the nip setting and depth of the roll grooving.

2.3 Granulators

The granulators used for final size reduction can be of various types. The most popular granulator available in Sri Lanka is the creper/hammermill. The shredder and extruder can also be used for final size reduction. The shredder gives the crumbs of finest size while the extruder and creper/hammermill give crumbs of comparatively larger size.

The granulator may be used as the sole means of comminution in the case of field coagula or as an intermediate stage prior to final comminution.

Some machines are fitted with feed rolls for better operation for processing of crepe and sheet rubber into TSR.

2.3.1 Shredder

This machine (Plate 5.2a) converts coagulum into small granules by a rotary cutting action, the cut pieces being discharged through a perforated screen. The cutting is commonly performed by three or more flying knives against two fixed knives. The size of the holes in the screen determines the size of the resultant granules.

In addition to the granular size, the choice of the screen apertures governs the amount of work done on the rubber, the degree of cleaning and the throughput of the machine, the speed of rotation, knife clearances, sharpness of the knives and screen holes may also affect granular size and machine throughput. Hence shredders require regular maintenance such as sharpening of knives, adjustment of knives etc.

2.3.2 Hammermill/creper-hammermill

Hammermills are being used quite extensively in block rubber factories in Sri Lanka. The basic principle of this machine is similar to that of a granulator, except that it has a set of "hammers" rotating horizontally in a solid chamber instead of sharp knives used in granulators. The hammers are made of hard carbon steel and are held by pins to the rotor discs. Some are held rigidly (fixed hammers) and others held at ends only to provide a swinging motion (swing hammers).

Because of "blunt cutting" the load on the motor is usually high and this requires a high installed electric motor with a HP of 70 - 100. The speed of rotation of hammers is around 2000 rpm.

Hammermills are used for both precleaning of field coagula and final size reduction of all grades of rubber. As the cutting is by beating and hammering the rubber, the end product is rough and well-sheared, which improves the drying characteristics of rubber and gives an excellent surface cleaning.

The present trend is to use a creper/hammermill, i.e. a pair of creper rolls fitted above the hammermill with minimum clearance between the bottom of the creper rolls and hammers, instead of a hammermill only. A creper/hammermill is preferred to other forms of hammermills as the electrical peak load and its occurrence during processing is much lower than that experienced from other types. This is because of the more efficient regulation of feed to the hammermill by the creper mounted close to the hammers.

Creper/hammermills are at present widely used for final size reduction of both latex and field grade materials.

2.3.3 Extruder/Pelletiser

The principle of the extruder is similar to that of the domestic meat mincer. Cutter knives work behind and in front of the die plate drilled with extrusion holes. This is almost exclusively used for final size reduction of latex grades of rubber (Plate 5.2b).

2.4 Dryers

Even though several types of dryers are used for drying TSR, most of them utilise the same basic drying principle of deep bed drying through hot air circulation at a temperature of 100 - 120^{0}C. Sometimes, deep bed drying uses temperatures as high as 130°C. Dryers vary in mechanical construction, handling and number of heating units.

The main function of the dryer is to dry the product obtained from the final size reduction unit, at the shortest economical time at high temperature but without affecting the physical properties of the final dry rubber. High dryer temperatures are not recommended since the resulting rubber would have poor physical properties. The heating systems employed in dryers are either indirect fixed heat exchangers or direct fixed heaters, using either a single unit for the entire drying or a series of units at different stages of drying.

The standard types of dryers are as follows:

1. Trolleys in batch or chamber in semi-continuous movement.
2. Trays, single or multiple layers with continuous or semi-continuous movement.
3. Apron drier with continuous movement within a chamber.

Out of the above three types, type (2) dryers are most popular in Sri Lanka. The essential mechanical components of the dryers are an air-circulation fan, burner, conveyor, cooling fan and ejectors.

Circulation fan: Both centrifugal and aerofoil fans are used for air circulation through the dryers. As these fans are normally subjected to humid conditions at high temperature, either bifurcated types or a belt driven (motor kept outside the dryer) system is used to protect the motor.

Burner: An oil burner suitable for burning light diesoline fuel is used. Inside the drying chamber of the dryer, atomising of oil occurs (i.e. conversion of liquid fuel into a fine spray of fuel droplets). Hence combustion of vaporized droplets takes place within a fraction of a second inside the combustion chamber.

Conveyors: Main chain conveyors are used in continuous tray movement. Roller chains with or without special attachments for locking the drying trays are used in conjunction with a guide plate or rolls.

Cooling fan: Cooling fans are fitted at the withdrawing end of the dryers, which suck air through hot rubber and the resultant hot air is also circulated into the wet zone of the dryer for better drying efficiency.

Ejectors: Ejectors are fitted just after the cooling fan for mechanical ejection of dried crumbs in the form of slabs.

2.5 Baling press

Freshly processed rubber is usually pressed warm (60°C) with pressures of up to 60 Metric tons applied for approximately 1 minute.

Hydraulic presses (Plate 5.3a) with either manual or automatic time interval settings or screw presses are used. Little seems to be gained by using high pressures and most presses in Sri Lanka operate at 30-60 tons. Most new presses are top-loading with hydraulic up-stroke. Other rotary presses have twin baling boxes and this facilitates simultaneous loading and pressing of rubber.

Screw presses, which are really modified versions of those used for conventional grades, use a mechanical load on the bale of rubber. Even though it costs less and has a high output, the bales are not well pressed. A higher loading rate or a long dwell time is therefore necessary for this type of press.

The objective of these presses is to make even-shaped and well compressed bales of rubber for final presentation.

3. PROCESSING OF LATEX INTO TSR

Latex collected at the centralised processing factory could be processed into TSR and the resulting TSR could be graded into SLR L, SLR 5L and SLR 5WF depending on their dirt content and colour. The manufacturing process is shown in the following flow diagram:

Flow diagram for processing of latex into TSR

Collection and preservation
↓
Reception and bulking
↓
Coagulation
↓
Initial processing
↓
Final size reduction
↓
Drying
↓
Weighing
↓
Bale pressing
↓
Bale wrapping
↓
Palletising

3.1 Collection and preservation

Latex is normally collected by bowsers from long distances for centralised factories. If latex is to be processed into light coloured grades of TSR (i.e. SLR L or SLR 5L) the ammonia-boric acid composite preservative system is preferable to other preservatives such as ammonia alone, sodium sulphite etc. Ammonia tends to darken the rubber, particularly if the preservation time exceeds 2½ hours. 0.03% ammonia and 0.2% boric acid on the dry weight are added to ensure adequate preservation before processing.

3.2 Reception and bulking

Undiluted latex which arrives at the factory is strained through a 40 mesh sieve into a bulking tank and bulked in a volume as large as possible to ensure maximum uniformity of production. This is followed by adding 0.04% sodium metabisulphite solution by weight of dry rubber to prevent enzymatic discolouration. Then stirring by paddle or mechanical stirrer should be carried out for about 3 minutes; then the latex is run down to coagulating tanks or coagulating troughs.

Dilution with water improves the colour of rubber, although it is not advisable unless absolutely necessary. Fractionation (i.e. removal of yellow fraction) is not recommended. Although it improves colour, it is tedious and also not economical. Bleaching agents should never be added to field latex in TSR manufacture. These chemicals are heat sensitive and an excess of these in combination with high temperature of drying, can give a much softer, darker and an oxidised (i.e. low P_O and PRI) rubber.

3.3 Coagulation

The standard procedure is as follows:

A sample of bulked latex is withdrawn and the amount of acid required for coagulation is determined by titration. The required amount of formic acid is then added to bring the pH to between 5.0 and 5.2. The coagulum is left for about 8 hours before milling.

3.4 Initial processing

In the case of latex coagulated in aluminium tanks, each coagulum is cut into small pieces before feeding into an extruder, or one or two passes are given through a creper before feeding into a granulator for final size reduction.

With trough coagulation the long thick coagulum is initially passed through a coagulum crusher where the coagulum is crushed removing serum water to form a ribbon. This is fed to a macerator followed by a creper, where washing, dewatering, and shearing occur, resulting in a thin clean blanket.

3.5 Final size reduction

After initial processing, blankets are fed into a Shredder/Turbomill/

Extruder through a conveyor belt, where final size reduction is achieved. The size of the crumbs depends on the type of machinery used in this step. The sheredder (Plate 5.2a) gives the smallest size crumbs while the extruder (Plate 5.2b) gives the largest size. Hence the extruder is particularly suitable for making latex grades of TSR.

The crumbs from the granulator are collected in the water tank where they are manually or mechanically loaded into boxes or trolleys (Plate 5.2c) and fed into the twin drier or KGSB dryer. If the final size reduction is by extruder, the extruded rubber is directly fed to the dryer (Plate 5.2d).

3.6 Drying

Drying is normally carried out in a deep bed dryer at about 100 – 120°C for 2 to 2½ hours.

There are instances where drying is carried out at higher temperatures to shorten drying time. Such higher temperatures of drying may result in a low P_O and PRI due to oxidation of rubber.

It is important to ensure that the final crumbs are discrete and uniform in size. Uneven crumb size may result in uneven drying, which is normally indicated by the presence of white spots.

Drying for too long or repeated drying should be avoided as this will lower P_O (initial Wallace plasticity number) and PRI (Plasticity Retention Index) of the resulting rubber. Boxes of dry crumbs, once they come out of the dryer, are mechanically ejected for easy removal.

3.7 Weighing

Exactly 33.33 kg of dried and cooled rubber crumbs or granules are weighed and loaded into the pressing box for pressing.

3.8 Baling

Baling of crumb rubber is normally done using screw or hydraulic presses (Plate 5.3a). Pressing of the rubber should be carried out only when the rubber is sufficiently cooled (i.e. around 60°C). This will minimise the change in properties of rubber and tearing of polythene. Pressed bales should have base dimensions of 380 × 570 mm or 330 × 675 mm. The height of the bale depends on the applied pressure and dwell time.

3.9 Wrapping

Polythene films are used to wrap the individual bales (Plate 5.3b), to separate different layers of bales and to line the inside of the crate. To perform their functions well, the polythene films must be capable of being stretched to a great extent before tearing. In addition, the polythene used must disperse into the rubber at the temperatures normally encountered in internal mixers. These characteristics are obtained with transparent low density polythene films of thickness 200 gauge (0.05 mm). For bale wrapping, crate lining and insertion as interleaves between bale layers, low density polythene films of thickness 0.05 mm are used. Films used for the strapping of bales must be opaque white and marked “strip before use”.

3.10 Palletising

The wooden pallets of base dimensions 1100 × 1425 mm or 1000 × 1200 mm are lined with cardboard or opaque (white or black) 0.15 mm thick polythene. Only cardboard-lined pallets are again lined with trasparent 0.05 mm thick polythene films to separate cardboard from rubber bales. The wrapped bales are then loaded into the polythene-lined pallet crate (Plate 5.3c).

Before loading, four U-shaped galvanized iron or aluminium guards should be placed at each side on the top of the crate to prevent bale wrapper damage and to hold the polythene liner in place. An interleaf of transparent, 0.05 mm thick polythene film should be placed in between layers of bales positioned in the crate.

When the pallets are completely loaded with rubber, some bales will be above the top of the crate. Further setting is then hastened by placing the pallet lid, a wooden platform and a tonne of rubber on top of the bottom pallet. Clamps or other devices may be used to prevent excessive bulging, which can cause the splitting of the bale wrappers. When the lid has settled down and the rubber is consolidated into the crate, the top pallet, wooden platform, pallet lid, U-shaped guards and thick polythene are removed. The polythene pallet liner is folded across the top of the rubber. After positioning the cardboard top cover and lid, the crate is strapped and sealed. Pallets are transferred and loaded, one on top of the other using fork lift trucks (Plate 5.3c).

4. PRODUCTION OF SLR 10, 20 AND 50 GRADES

The method of manufacture of SLR 10, 20 and 50 depends not only on the nature of raw materials but also on the particular grade to be achieved. The manufacturing methods and raw materials used also vary from one factory to another. Generally the raw materials used are cup lumps, tree-laces coagulum slabs, scrap crepe, off grade latex crepe and lower grades of RSS. Due to difference in quality, strict control of the processing practices should be adopted to achieve a required grade. This may require efficient blending procedures and chemical treatments to maintain consistency in quality. The degree of consistency, the level of properties to be achieved and the type of materials available will determine the processing procedure to be adopted. Blends of cup lumps, panel scrap, bucket coagulum, sheet cuttings and chippings are taken to make TSR 10, 20 and 50 grades either separately or as blends. A high percentage of good cup lumps and sheet cuttings is used to make TSR 10 and 20; increase in panel scrap and low grades of coagula containing high foreign matter content lowers the grade of TSR manufactured.

Use of skim rubber which is a byproduct of the centrifuged latex industry is not permitted in TSR manufacture. The use of any kind of vulcanized rubber like the crumbs of gloves and of microcellular sheets is also not permitted.

Processing steps of these grades are similar to those of latex grades, from drying to palletizing.

Flow diagram for SLR 10, 20 and 50 manufacture

Storage of raw material
↓
Pre-cleaning
↓
Final size reduction
↓
Chemical treatment
↓
Drying
↓
Weighing
↓
Baling
↓
Bale wrapping
↓
Palletising

4.1 Storage of raw material

There are various methods of storing field grade materials (Plate 5.1a). Each of these methods has a different effect on the quality of the rubber. Many factories prefer to store their rubber under water for easy cleaning. Soaking of hard, aged, field grades helps in the process of dirt removal. It also softens the rubber which consequently facilitates processing and blending operations. However, oversoaking of this rubber should be avoided. It has been noted that the Po and PRI of loose cup lumps and shell scrap are susceptible to reduction, when soaked over a long period of time. Therefore, these materials should be stored dry, but should not be directly exposed to sunlight for too long.

4.2 Pre-cleaning, blending and final size reduction

A lump breaker (Plate 5.1b) is usually employed to break the cup lumps into manageable pieces before the pre-cleaning operation.

Pre-cleaning of dirty raw materials can then be carried out on a macerator, or hammermill. The following combination is commonly used rather than individually:

Macerator (multiple passes)
↓
Creper (multiple passes)
↓
Granulator or hammermill

A rough diamond macerator is normally placed before the creper. This arrangement has proved to be more efficient and effective in operation. The macerator may be arranged line-ahead or side by side. During these operations the rubber is cleaned and blended (Plate 5.1c) appropriately. Well formed blankets are then fed into the granulator or hammermill.

The cutting action of the granulator knife exposes new surfaces of rubber and hence greatly facilitates dirt removal. The hammermill also gives good surface cleaning but less size reduction unlike in the case of granulation.

The above combination of steps may be repeated in cases where excessive dirt removal and blending are necessary at this stage.

4.3 Chemical treatment

Where needed, the PRI of rubber can be increased by treatment in chemical treatment tanks (Plate 5.2b) with certain chemicals. Several such chemicals are available, among which oxalic acid and phosphoric acid are very effective and dipping crumbs in a dilute solution (1%) of these chemicals before drying is permitted.

5. MANUFACTURE OF SLR 5 FROM RSS

Raw material used for SLR 5 manufacture is restricted to sheet materials only. Sheet material needs no chemical treatment as it has a very high P_O and PRI. The factory flow line for manufacture of SLR 5 is as follows.

Bale cutting or stripping of bales or blocks
↓
Maceration (Multiple press)
↓
Creping (multiple passes)
↓
Granulation or hammer-milling
(Final size reduction)
↓
Drying
↓
Weighing
↓
Bale pressing
↓
Bale wrapping
↓
Palletising

6. SPECIFICATIONS OF CONVENTIONAL GRADES

The presentation of the conventional forms of rubber in technically specified forms is also allowed in the TSR scheme. But uniformity and consistency in quality can be achieved only when higher grades of RSS (1, 2 and 3) and thin pale crepe (1X and 1) are used. If the starting material is RSS the method of manufacture involves cleaning surfaces of the sheets by brushing followed by folding or cutting into standard size. Then sheets are dried in a drier for about 30 – 60 minutes at 100°C to remove surface moisture. Pressing, weighing, bale pressing, wrapping and palletising operations are similar to other TSR grades. In the case of thin pale crepe after inspection and sorting laces are laminated and cut into standard size followed by pressing.

SLR 5 (RSS) could be manufactured from RSS 1, 2 and 3 by this method and this should conform to raw rubber specifications for SLR 5.

Thin pale crepe No. 1X and 1 could also be converted into block form and the resulting rubber could be graded into SLR L (LC) depending on specification parameters and colour.

Plate 5.1. Initial processing of scrap in TSR manufacture. **a** Scrap material (mainly cup lumps and tree laces); **b** Lump breaker; **c** Blending of hammer milled rubber in "macro blenders".

Plate 5.2. Equipment for final size reduction and drying. **a** Shredder; **b** Extruder and chemical treatment tank; **c** Mechanical feeding of crumbs into trolley boxes; **d**. Deep bed dryer.

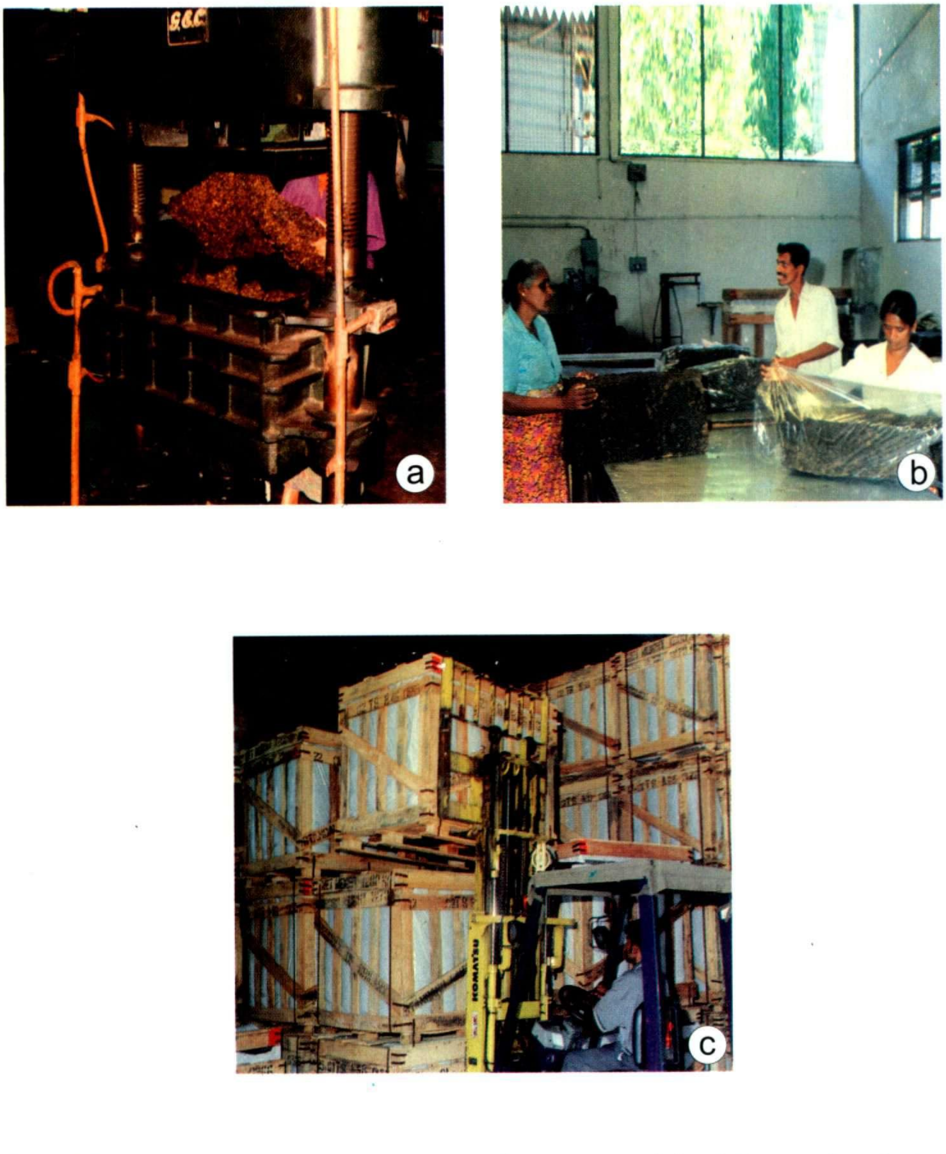

Plate 5.3. Baling and palletizing. **a** Hydraulic press used for bale pressing; **b** Bale wrapping in polythene; **c** Rubber bales palletized in wooden crates are loaded, one on top of the other using fork-lift trucks.

Chapter 6

Centrifuged latex[*]

W.M.G. Seneviratne and P.H. Sarath Kumara

1. INTRODUCTION

Natural rubber latex as obtained from the tree is in the form of a dispersion consisting mainly of rubber particles in water, having an average rubber content of around 30%. This concentration of rubber expressed as a percentage is referred to as the "Dry Rubber Content" (DRC). The DRC of latex may vary with the clone, the season, climatic condition, age and health of the tree, soil fertility and tapping intensity. By centrifuging, the DRC of field latex can be increased to 60%.

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[*] Adapted from "A Handbook of Rubber Culture and Processing", 1983

Centrifuged latex commonly used in Sri Lanka is single centrifuged, but double or multiple centrifuged latex could also be manufactured on customer requests. The common preservative for centrifuged concentrated latex is ammonia and depending upon the ammonia content the latices can be high ammonia (HA) or low ammonia (LA). HA latices contain only ammonia, whereas the LA latices in addition to ammonia contain secondary preservatives and differ from each other in the type of secondary preservatives used. Secondary preservatives can be boric acid, tetramethylthiuram disulphide (TMTD)/ZnO, etc. Table 6.1 gives common preservative systems for centrifuged latex. Formaldehyde and KOH can also be used as preservatives for concentrated NR latex. The preservative system used depends upon customer requirements.

The high concentration of rubber in centrifuged latex is quite advantageous in that it lowers the cost of transport and shipping. Also this high concentration makes it an attractive proposition for latex-based industries such as production of dipped goods, rubber thread, latex foam, cast products, and also in applications such as carpet backing, rubberized coir, adhesives, etc.

Table 6.1. Preservative systems for centrifuged latex

Type	Preservative system
1. High ammonia (HA)	0.7% ammonia
2. Low ammonia (LA)	
(a) LA – BA	0.2% ammonia + 0.2% boric acid + 0.05% lauric acid
(b) LA – ZDC	0.2% ammonia + 0.1% zinc diethyldithiocarbamate + 0.05% lauric acid
(c) LA - TMTD/ZnO (LATZ)	0.2% ammonia + 0.013% tetramethylthiuramdisulphide + 0.013% zinc oxide + 0.05% lauric acid

2. PREPARATION OF CHEMICAL SOLUTIONS

2.1 10% ammonia solution

The stock solution is prepared by diluting 1 litre of 25% strong ammonia with 1.5 litres of water. If ammonia comes in cylinders, 10 kg of ammonia gas is bubbled through 90 kg of water to make a 10% solution.

2. 2 10% ammonium laurate solution

To make a 10% solution, 4.6 kg of lauric acid is dissolved in 4.0 kg of hot water and 5 kg of 10% ammonia solution is added before mixing the contents well. Then 4.5 kg of cool water is added to the mixture to make it a 10% solution.

2.3 25% TMTD/ZnO dispersion

Dispersion is prepared by ball milling a mixture of the following ingredients for approximately 48 hours in a suitable ball mill until a stable dispersion is obtained.

TMTD	12.5 parts
ZnO	12.5 parts
Dispersol LR	1 part
Bentanoite clay	0.5 parts
Water	73.5 parts

2.4 15% DAHP solution

DAHP 15% solution is prepared by mixing 115g of phosphoric acid (H_3PO_4) with 136 g of 25% NH_4OH solution and adding water up to a total weight of 880g.

3. PRESERVATION OF FIELD LATEX

The first important step in the preparation of a consistent quality concentrate is the proper preservation of latex in the field and subsequently at the factory. Ammonia is considered to be the most cost-effective preservative at present. Ammoniation at an early stage, i.e. at the time of collection of latex in the field inhibits bacterial growth early. Such treatment ensures latex with low volatile fatty acid number (VFA No.), which is an essential prerequisite for properly preserved centrifuged latex.

3.1 Preservation in the field

For the manufacture of HA latex, 10% ammonia solution is added to latex in the field at the very earliest stage at the rate of 4 litres for 100 litres of latex, to give an ammonia content of approximately 0.4%.

For the manufacture of LATZ latex, the ammonia level in the field can be reduced to 0.3% with the addition of a secondary preservative. However, the secondary preservative is usually added as soon as the ammoniated latex arrives at the factory.

3.2 Preservation at the factory

Field latex should be first sieved using a 60-mesh sieve, preferably made of monel metal, and then bulked. The DRC of the latex should be determined after bulking to assess the suitability of the raw material. Latex of DRC below 25% is unsatisfactory for processing into concentrated latex. If the DRC is found to be satisfactory the latex is ammoniated with ammonia gas to bring the ammonia level to about 0.4% by weight of latex for manufacture of HA centrifuged latex. If it is essential to keep field latex for a period of 2 to 3 days before further processing, it is necessary to increase the ammonia content up to 0.7%.

Field latex collected for the manufacture of LA latex is further preserved with a secondary preservative no sooner the latex arrives at the factory. The 25% dispersion of the secondary preservative i.e. TMTD/ZnO is added at the rate of 1 litre for 1000 litres of latex so that the level of TMTD/ZnO would be 0.025% on latex.

3.3 Removal of magnesium

Presence of magnesium ions in latex enhances bacterial growth and activity which causes the development of volatile fatty acids (VFA). Therefore, it is important to remove magnesium ions to ensure proper preservation. Magnesium content of field latex should be brought down to 80-100 ppm levels by the addition of DAHP prior to centrifuging. The rest of the magnesium is precipitated in the natural process involving ammonia and naturally present phosphates which would ultimately bring the level of magnesium in centrifuged latex to around the 40 ppm level. This precipitation process will take at least 24 hours to complete and therefore, it is quite important to keep the latex with DAHP added to stand undisturbed for 24 hours in the settling tanks. Magnesium is precipitated at the bottom of the settling tanks in the form of $MgNH_4PO_4$ as sludge.

$$Mg^{2+} + (NH_4)_2HPO_4 \longrightarrow Mg\,NH_4PO_4 \downarrow + NH_4^+$$

Removal of magnesium as sludge helps to improve the quality of the concentrate as well as the efficiency of the centrifuge. This sludge, if not properly removed, would otherwise get deposited inside the bowl of the centrifuge.

Addition of correct dosage of DAHP to remove magnesium ions in field latex will prevent subsequent problems of latex thickening as would otherwise be encountered due to the presence of phosphate ions in excess. This can be done by first determining the magnesium content in latex and then calculating the amount of DAHP required to precipitate the magnesium.

The following formula could be used to calculate the quantity of DAHP required to bring down the magnesium level to 100 ppm. The rest up to about 70 ppm is precipitated in the natural process.

$$W_p = \frac{(m - 100) \times W_L \times 132}{10\,C \times 24}$$

m = magnesium content of latex in ppm
W_L = Weight of latex in kg
W_p = Weight of DAHP solution in grams
C = Concentration of DAHP solution as a percentage

The sludge formed as magnesium ammonium phosphate ($MgNH_4PO_4$) must be removed either by using a sludge trap or by decantation from the settling tanks. It is advisable to check the VFA number of latex to see whether it is well preserved, as latices with VFA No. greater than 0.05 at this stage would not yield stable concentrates.

4. PREPARATION OF CENTRIFUGED LATEX

Normal field latex is composed of small rubber particles, of diameter less than one micron (1/1000 mm) and lighter than the surrounding serum. There may be other heavier non-rubber substances. The rubber particles being lighter tend to rise to the top, though hindered by gravity and the inherent Brownian motion. This natural concentration or surfacing is so slow that a rubber particle of 1/4000 mm diameter has been found to take a week to rise a distance of 2 mm in field latex.

4.1 Mechanism of centrifuging

Adequately preserved field latex is transferred from the settling tanks to the centrifuges (Plate 6.1a) where separation of rubber particles from the watery serum takes place.

In a centrifuge rotating at 7000-10,000 rpm, a force of about 8000 times that of gravity is generated, enabling fast separation. A latex centrifuge is made up of a large number of cones of stainless steel arranged one on top of the other. The latex is first fed to a feed cup on top of the centrifuge where the liquid level is held constant by means of a float. The latex flows by gravity through the feed tube into the centre of the rotating bowl where the centrifugal action forces it through a series of distribution tubes in the distributor (Plate 6.1b), into the disk stack. When the latex flows upwards through the holes in the disk stack (Fig. 6.1), it is split into two fractions. The heavier particles are forced outward and the lighter particles inward. Thus, at the top of the centrifuge the output runs into two streams, one consisting of rubber (average volume = 45% from the total throughput and DRC = 60%) and the other of serum containing so called non rubber substances rich skim rubber (average volume = 55% from the total throughput and DRC=3-6%).

The skim flows to the bowl periphery where it passes outside the top disc and is discharged into the skim cover, through regulating screws. The concentrate is displaced towards the centre where it flows upward and is thrown out into the cream cover through a series of holes at the neck of the top disc. Those latex particles which do not separate immediately from the skim flow to the periphery and return to the centre along the upper surface of each disc after being released at the outer part of the disc stack.

During centrifuging the heavy sludge in the feed is separated inside the distributor and gets deposited as a layer around the distribution tubes. The yellowish lighter sludge separating in the disc stack is collected in the solids-holding space at the periphery of the bowl.

When the sludge space in the distributor or the passage through the machine is full of sludge or coagulated latex (Plate 6.1b), the liquid level in the distributor tends to move until the liquid flows over the top of the distributor and is thrown into a special chamber of covers, from where it will flow out along the frame. This is a warning for the operator that the machine should be stopped for cleaning.

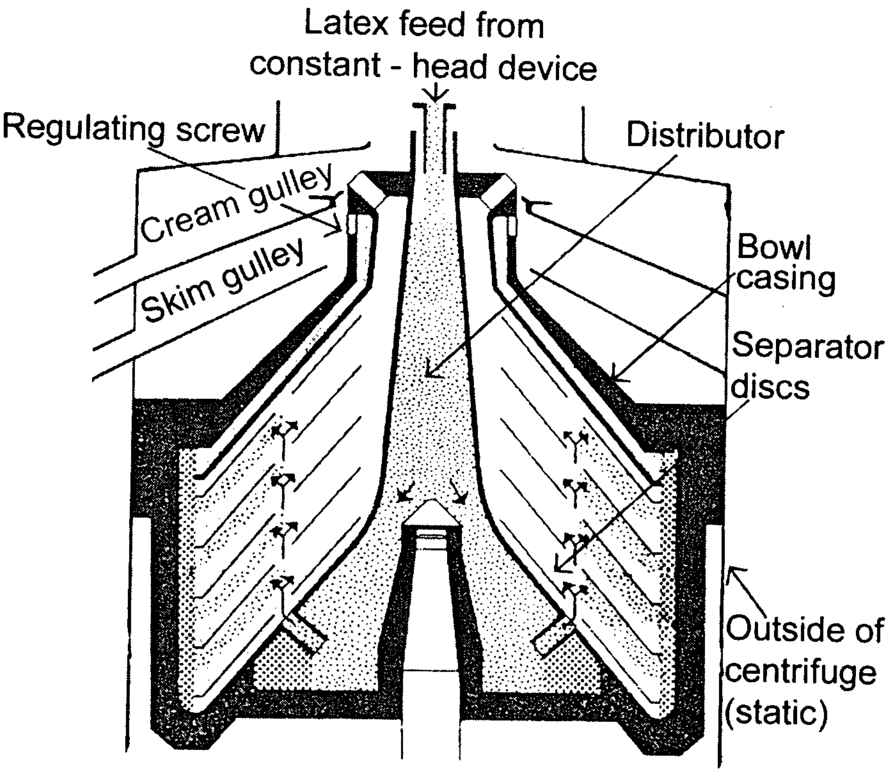

Fig. 6.1. Longitudinal section through bowl and upper part of the machine

4.2 Adjustment of the rate of feed

The amount of feed liquid flowing into the bowl determines the feed capacity and can be adjusted by

(a) Changing the feed pipe (a set of feed pipes with different diameters is supplied with every separator). A larger diameter gives higher feed rates.

(b) Changing the height of the liquid level in the feed cup.

4.3 Adjustment of the skim screws:

DRC of skim latex and the latex concentrate can be adjusted by skim screws. Shorter skim screws give more skim latex with lower DRC and lesser content of cream with higher DRC. A higher feed capacity generally requires a shorter skim screw to obtain the same DRC of the cream. A longer running time also generally requires shorter screws.

5. PRESERVATION OF CENTRIFUGED LATEX

Most of the ammonia and the other chemicals added for preservation are removed with the serum thereby reducing the effective level of preservation in the concentrate. Therefore, the concentrate should be ammoniated further to bring the level up to 0.7% (w/w) for HA centrifuged latex and up to 0.2% (w/w) for LATZ latex. Addition of 0.5 litres of 25% dispersion of TMTD/ZnO to latex after centrifuging has been found to be adequate to increase the TMTD/ZnO level up to 0.025% in LA latex.

The other fact is that the ammonia preserved latex is stabilised by the anions of fatty acids formed by the hydrolysis of naturally present phospholipids by ammonia. This stabilisation is further enhanced by adding a 10% solution of ammonium laurate as the stabilizer at the rate of 1 litre for 200 litres of latex to give a concentration of 0.05% on latex.

Ammonia level of centrifuged latex in storage (Plate 6.1c) should be periodically checked and the required quantity of gaseous ammonia should be bubbled through latex to maintain the required ammonia level. Incorporation of ammonia as a solution is undesirable as it will reduce the DRC of the concentrate.

6. SEPARATING EFFICIENCY

The latex particles are so small that even high efficiency of the separators (centrifuges) cannot separate them all at practical feed rates, and the skim liquid contains a certain amount of rubber. To measure the efficiency of a separator and of a factory, the bowl concentrating efficiency and the total factory efficiency are important indicators.

6.1 Bowl concentrating efficiency

This gives an idea of how much of dry rubber in the feed will be recovered as dry rubber in the cream after centrifuging. On the assumption that none of the dry rubber is left in the machine, a simple formula for bowl concentrating efficiency can be written as follows;

$$\text{BCE} = \frac{C\,(F-S)}{F\,(C-S)} \times 100\%$$

where,

C = % DRC in cream
S = % DRC in Skim
F = % DRC in Feed

Following factors affect the bowl efficiency;

a. Quality of feed
b. Running time
c. DRC in the feed
d. Rate of feed
e. Rate of Concentration (DRC in Cream)

Average bowl efficiencies of the centrifuging machines of Alfa-Laval, one of the largest manufacturers of centrifuging machines in the world are given in table 6.2.

Table 6.2. Types of Alfa-Laval machines their typical capacities and efficiencies

Model	**Feed capacity at 90% BE (litres/hour)**	**Bowl efficiency (BE) at a feed rate of 480l/hour**
LRH 200/310	320	87.5%
LRH 410	480	89.5%
LRH 510	640	91.5%

6.2 Total factory efficiency

Total factory efficiency of a factory could be estimated from the following equation.

$$\text{TFE} = \frac{W_c + W_s + W_w}{W_F} \times 100$$

where,

W_C = wt. of dry rubber in cream
W_S = wt. of dry rubber collected from skim
W_W = wt. of dry rubber collected from washings
W_F = wt. of dry rubber in the feed

A total factory efficiency of more than 98% can be expected from an efficiently working factory.

7. TEST METHODS AND SPECIFICATIONS

Concentrated latex must be thoroughly tested at every stage of production and before shipment. The relevant testing procedures together with ISO specifications are given in table 6.3.

Table 6.3. Specifications for centrifuged or creamed ammonia preserved natural rubber latex [ISO 2004-1979(E)]

Characteristic	Limits					Method of test
	type HA	type LA	type XA	type HA creamed	type LA creamed	
Total solids content[1], % (m/m), min.	61.5	61.5	61.5	66.0	66.0	ISO 124
Dry rubber content, % (m/m), min.	60.0	60.0	60.0	64.0	64.0	ISO 126
Non-rubber solids[2], % (m/m), max.	2.0	2.0	2.0	2.0	2.0	-
Alkalinity (as NH_3), % (m/m), on latex.	0.60 min.	0.29 max.	0.30 min.	0.55 min.	0.35 max.	ISO 125
Mechanical stability[3], seconds, min.	650	650	650	650	650	ISO 35
Coagulum content, % (m/m), max.	0.05	0.05	0.05	0.05	0.05	ISO 706
Copper content, mg/kg of total solids, max.	8	8	8	8	8	ISO/R 1654
Manganese content, mg/kg of total solids, max.	8	8	8	8	8	ISO 1655
Sludge content, % (m/m), max.	0.10	0.10	0.10	0.10	0.10	ISO 2005
Volatile fatty acid number (VFA)	As agreed by the interested parties but not to exceed 0.20					ISO 506
KOH number[4]	As agreed by the interested parties but not to exceed 0.20				for all five types	ISO 127
Colour on visual inspection	No pronounced blue or gray					-
Odour after neutralization with boric acid	No pronounced odour of putrefaction					-

1. Total solids content is an optional requirement.
2. Difference between total solids content and dry rubber content
3. A minimum mechanical stability may be required which is greater than the minimum value specified.
4. If the latex contains boric acid, the KOH number may exceed the specified value by an amount equivalent to the boric acid content as determined by the method specified in ISO 1802.

It must be mentioned that the test results only give an indication of the quality of the latex concentrate as it is manufactured. However, sometimes the latex may have to be made to suit the individual consumer's requirements, as decided by the buyer. In such cases the specifications are laid down by the buyer.

Deviations of the test results from the required specified values may be due to various reasons, some of which are given below:

7.1 High or low total solids/dry rubber content

This could happen as a result of latex not being homogenized properly in the storage drums or tanks. A sample drawn from the top without homogenizing normally gives a higher value for solids and DRC than one drawn from the bottom. Sampling procedure for rubber latex is described in ISO 123.

7.2 Low alkalinity/pH

This is generally due to loss of ammonia during storage and could be prevented by closing storage tanks and drums with airtight lids. Otherwise it would lead to poor preservation, the result of which would be putrefied latex with a bad odour and poor stability.

7.3 High or low mechanical stability

The stability time of centrifuged latex tends to increase gradually after preparation, the reason for this being the formation of ammonium salts of long chain fatty acids from the hydrolysis of some non-rubber substances. Addition of low levels of ammonium or potassium laurate improves MST of low MST latices. A low value of MST may be due to poor preservation unless latex is fresh.

7.4 Volatile fatty acids (VFA)

Volatile fatty acids are formed by bacterial activity on non-rubber substances found in latex and hence the VFA number corresponds to the state of preservation of latex. A value greater than 0.05 indicates inadequate preservation and the buyers may reject latex.

7.5 Potassium hydroxide (KOH) number

This is a measure of total acids both volatile as well as non-volatile present in latex. A high KOH number of latex having a low VFA number indicates the extent of maturity and that of latex having a higher VFA number indicates poor preservation.

7.6 Trace metals

Normally the latex concentrate contains low levels of copper and manganese. High levels of either of these metals occur through contamination on contact with copper or manganese alloys. The presence of iron is usually attributed to bad lining of iron drums and can discolour latex.

8. GENERAL LAYOUT OF A LATEX CENTRIFUGING FACTORY

It is advantageous to design the centrifuging factory to utilize maximum gravity flow for latex feeding and storing. A sketch of a centrifuging factory using a gravity feed system is shown in Fig.6.2. The capacity of this is 22,500 litres per 8 hour shift. Effective means should be provided for proper disposal of serum and other effluents.

9. SKIM RUBBER

Skim rubber is obtained by the coagulation of the skim or diluted latex fraction obtained as a by-product during the preparation of centrifuged latex. The rubber content in the skim fraction is very small and is usually 4-6%, with higher amounts of non-rubber substances. The composition varies with the type of centrifuge, rate of through-put and the method of processing. Because of its low DRC and the presence of ammonia, skim latex is somewhat difficult to coagulate into a coherent coagulum. The usual coagulant is sulphuric acid, but calcium chloride and formic acid are also employed. Deammoniation of skim latex will help to reduce the consumption of acid for coagulation. This can be done simply by aeration of latex with compressed air, while a stream of air being passed over the latex. The coagulum is made either into sheet or crepe and dried. The dried product is similar in appearance to normal smoked sheet or brown crepe. In some instances the coagulum is soaked in water before and after creping and treated with a fungicide such as formalin to obtain a light colour and to reduce mould growth.

Processed skim rubber contains 75 – 85% rubber hydrocarbon, 9-18% protein and 5-10% acetone soluble material. It can be readily vulcanised using acidic accelerators with a corresponding tendency to scorch. With alkaline accelerators it vulcanises at normal rates. Vulcanisates obtained with skim rubber are several degrees harder than those of the normal grades and this could be advantageous for certain specialized applications such as manufacture of rice huller rollers.

One of the main disadvantages of skim rubber is its widely variable properties due to the wide variability of its composition, but the variability of the material from the same source is not very significant.

It is marketed as sheet and crepe, but it should not be mixed with normal grades.

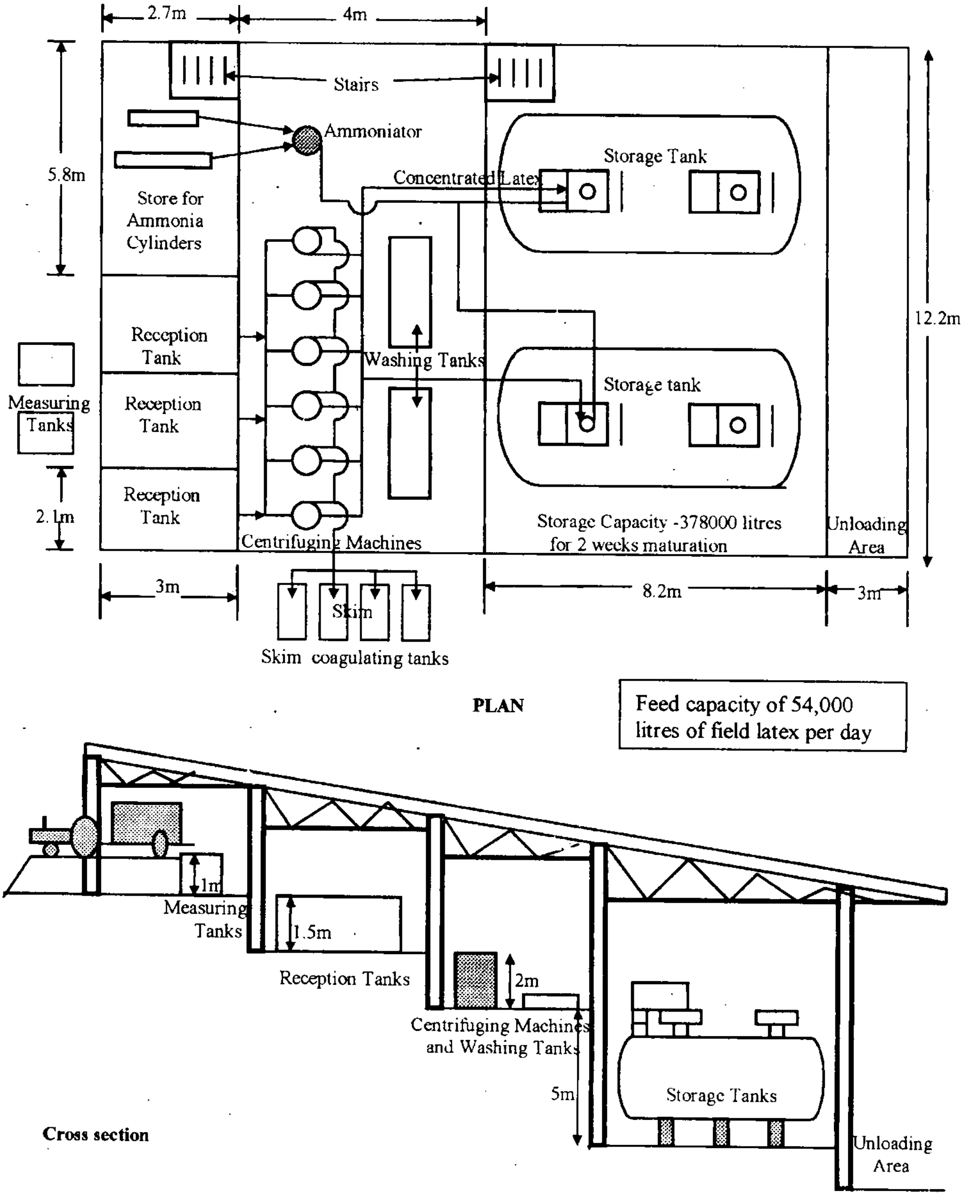

Fig.6.2. Concentrate factory layout

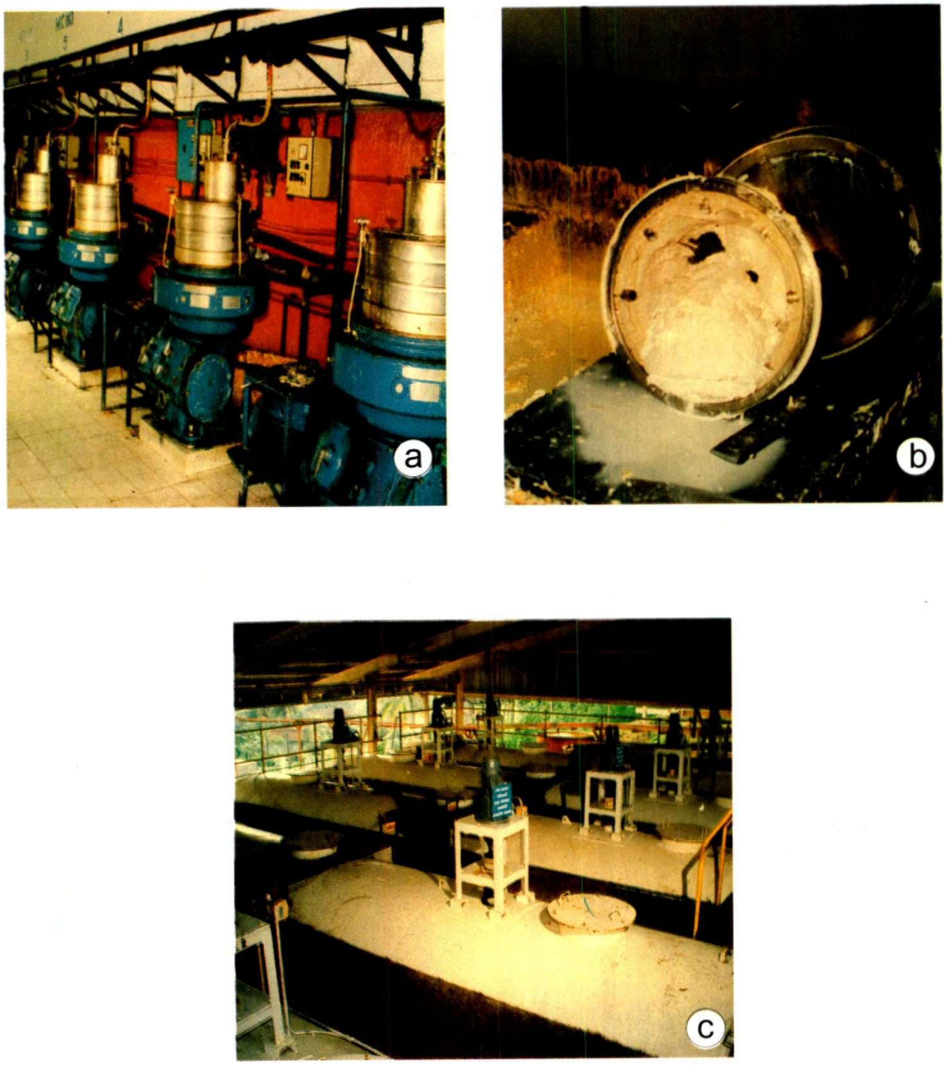

Plate 6.1. Equipment used for latex centrifuging. **a** A series of centrifuging machines; **b** The distributor showing sludge deposited and bowl coagulum. Disc-stack also is shown behind the distributor; **c** Large storage tanks for centrifuged latex.

Chapter 7

Value added grades of natural rubber*

K.G. Karnika de Silva

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    - 3.2 Low Viscosity (LV) grades
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        - 3.2.2 Presentation of CV and LV rubbers
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* Adapted from "A Handbook of Rubber Culture and Processing", 1983

1. INTRODUCTION

Natural Rubber (NR) obtained from the latex of *Hevea brasiliensis* is an excellent elastomer. Its main advantages over the synthetic rubbers in general are its superior dynamic properties, low heat build up, excellent tack and good green strength and it is virtually free from monomers.

Some of the commercially available value added grades of NR are,

- Deproteinised Natural Rubber/Low Nitrogen NR
- Constant Viscosity (CV) Rubber/Low Viscosity (LV) Rubber
- Methyl Methacrylate Grafted Natural Rubber (Heveaplus MG)
- Superior Processing (SP) Rubber
- Thermoplastic Natural Rubber (TPNR)
- Oil Extended Natural Rubber (OENR)
- Powdered/Granular Rubber
- Depolymerised Rubber/Liquid Natural Rubber
- Positex
- Cyclised Rubber
- Chlorinated Natural Rubber
- Epoxidized Natural Rubber

2. DEPROTEINISED NATURAL RUBBER (DPNR)

Natural rubber produced by acid coagulation contains about 2.5% proteins. Presence of proteins along with other non-rubber substances results in absorption of water, which causes variability in modulus, resilience, creep and stress relaxation of the rubber. The insulation properties of the rubber are also impaired.

Various methods of production of deproteinised natural rubber are based on enzymic conversion of proteins present in natural rubber. In one process, latex is treated with 2 parts per hundred rubber (phr) potassium naphthenate and 0.3 phr superase for 24 hours followed by coagulation of the rubber. In another method, latex stabilized with 1 phr Vulcastab LW is treated with 1 phr of an enzyme Anilozyme P-10, for 20 hrs at 50°C. DPNR can also be produced by treating the latex either with the enzyme papain or with pineapple juice, which contains another enzyme bromelin. In these processes the enzyme treatment also results in the coagulation of the rubber. It has also been found that the deprotenisation and coagulation could be effected using half the dosage of papain along with half the normal dosage of acid required for acid coagulation. The rubber coagulated in this manner could be processed into crepe/sheet rubber.

The recommended procedure for the preparation of DPNR by papain treatment is as follows:

- Field latex is diluted with 3 volumes of water containing a non-ionic soap (Nonidet, T) at 0.06 phr - (optional) and a suspension of papain at 0.06 phr in water (papain to water 1:100 w/v) is added, thoroughly mixed and allowed to coagulate overnight. The coagulum is washed after 48 hrs of maturation and processed into crepe rubber. Drying is done in a hot air drying tower, which takes about 6 days.
- DPNR prepared by all the above methods has been found to have superior dynamic properties. Hence, rubber with low protein content is preferred for the manufacture of engineering components, bridge bearings, building mounts and aircraft tyres. DPNR has also been found to be suitable for the manufacture of some other modified rubber grades.

DPNR is a pure grade of rubber and its nitrogen content and ash content should be below 0.15% and 0.12% respectively. The other specifications such as dirt, volatile matter, Po and PRI are the same as those of the SLR 5 grade of rubber.

3. CONSTANT VISCOSITY (CV) RUBBER

Viscosity or hardness of raw natural rubber increases steadily during storage and is referred to as storage-hardening. This is not desirable for manufacturing rubber articles as more energy is required for processing the storage-hardened rubber. This hardening effect of rubber is prevented by adding 0.15% of hydroxylamine salts on a w/w basis to latex prior to coagulation.

The recommended method of manufacture of CV rubber is as follows:

- Hydroxylamine as its hydrochloride or neutral sulphate is the standard reagent used for the production of constant viscosity rubber. Hydrolylamine neutral sulphate is the preferred chemical as it is cheaper than hydroxylamine hydrochloride. Since these two chemicals cause a certain amount of discoloration, to obtain light coloured, viscosity stabilized rubber, semicarbazide could be used.
- Ammonia is added as an anticoagulant at 0.01 - 0.10% on latex, to prevent precoagulation. The use of formalin as an anticoagulant is avoided due to its reaction with hydroxylamine salts and the use of sodium sulphite is not recommended as it causes discolouration. The latex is then treated with 5%

aqueous solution of sodium metabisulphite (0.04% by weight of rubber content) to prevent enzymatic discolouration. Then a 10% aqueous hydroxylamine neutral sulphate (0.15% by weight of rubber) is added and mixed with the latex while stirring and stirring is continued for a further 3 minutes before coagulation with formic acid. Coagulated rubber is then processed into block rubber. Alternatively the coagulum could be processed into crepe or even sheet rubber.

3.1 Measurement of viscosity

Viscosity of raw rubber is usually measured using a Mooney viscometer with a large rotor and expressed as Mooney units (ML + 4) at 100°C. However, for production control, Wallace plasticity measurements are increasingly used. This is due to the ease of Wallace plasticity measurements and the lower cost of the instrument.

Mooney viscosity levels of PB 86, a popular clone in Sri Lanka in the past, is around 74-80 and CV rubbers with lower Mooney values can be prepared by adding a small quantity of peptiser during the manufacturing process. The quantity of peptiser necessary would depend on the viscosity level required.

It has been found that the Mooney viscosity values vary widely between different clones and the values obtained for some of the clones in Sri Lanka are given below:

Mooney viscosity values of rubber from some clones

RRIC 100 - 80
RRIC 101 - 89
RRIC 102 - 72
RRIC 103 - 80
RRIM 600 - 68
PB 86 - 74

The most popular CV Grades are CV 50 and CV 60, the number denoting the Mooney viscosity values. The CV grades are used for special extrusion and moulded articles. There is a growing demand for these grades in the market.

Grade	**Mooney viscosity range**
CV 50	45 - 55
CV 55	50 - 60
CV 60	55 - 65
CV 65	60 - 70
CV 70	65 - 75

Commercially CV rubber is produced within the low range of 50 - 65 Mooney units, which ensures premastication savings to the consumer.

3.2 Low Viscosity (LV) grades

Low Viscosity rubber is prepared by the addition of a fixed quantity of an inert plasticizer (a non-staining naphthenic rubber process oil) to the viscosity stabilized rubber.

The types of LV rubbers and their Mooney viscosity ranges are given below:

Grade	**Mooney viscosity range**
LV 45	40 - 45
LV 50	45 - 55
LV 55	50 - 60
LV 60	55 - 65
LV 65	60 - 70

3.2.1 Manufacture of LV rubber

LV rubber contains four parts of non-discoloring oil per hundred parts of rubber.

In the production of LV rubber, it is necessary to ensure consistency in the Mooney viscosity level as well as the oil content, assessed by the acetone extract values. A stable oil emulsion is a prerequisite for the production of this and can be obtained by stirring the components given in Table 7.1 with the aid of an emulsifier for about 10 minutes. Portion B should be added to portion A whilst stirring.

Table 7.1. Recommended formulation for naphthenic rubber process oil emulsion

		Parts by weight
Portion A	Naphthenic oil	100
	Oleic acid	1.5 – 2.0
Portion B	Water	30
	Ammonia	0.1 – 0.2

Oil emulsion is added to latex prior to the addition of acid. However, it is necessary to ensure that the latex is stable and has a pH of about 8, before the addition of the oil emulsion. The speed of stirring during the incorporation of the oil emulsion to latex should be slow. Stirrer should have long paddles.

3.2.2 Presentation of CV and LV rubbers

Producers of viscosity stabilized rubber mark the product as either CV or LV. The use of these marks without further qualifications indicates that the rubber has a raw Mooney viscosity (VR) of 60 ± 5 in the case of CV and 50±5 in the case of LV. These two grades together are expected to comprise most of the viscosity-stabilised rubbers produced. When the viscosity values are different, then it is mandatory for producers to use CV/LV markings with appropriate qualifying indications.

3.2.3 Testing CV and LV rubbers

In production control, the Accelerated Storage Hardening Test (ASHT) is used. The procedure is simple and involves the measurement of Wallace plasticity (Po) before and after subjecting the sample for a short period to conditions which accelerate the storage hardening reactions. The recommended procedure involves storing the test pellets of rubber over phosphorus pentoxide at atmospheric pressure at 60°C for 24 hours. The resultant increase in Po should be below 8 units for the rubber to qualify as a viscosity stabilized grade.

4. GRAFTED RUBBER - NATURAL RUBBER/POLY METHYL METHACRYLATE GRAFT COPOLYMERS (HEVEAPLUS MG)

Heveaplus MG rubbers are graft copolymers of natural rubber and polymethylmethacrylate where the grafted polymethylmethacrylate is present essentially as relatively long and large side chains attached to the NR molecule.

These grades of rubbers can be prepared by graft copolymerization of methyl methacrylate in natural rubber latex. Although MG lattices may be prepared at almost any desired ratio of polymethylmethacrylate to rubber, the most commonly used materials contain 30% or 49% polymethylmethacrylate, designated MG 30 and MG 49 respectively.

The formulations used to prepare MG 30 and MG 49 are as follows:

Formulations for the preparation of MG 30 and MG 49

	MG 30	MG 49
Latex		
Rubber content	700	500
Ammonia (0.45% of latex)	10.4	7.5
Monomer emulsion		
Monomer (Methylmethacrylate)	300	500
Cumene hydroperoxide (CHP) 0.25% of rubber (as a 70% solution)	2.5	1.8
Water	150	250
Oleic acid (1% on monomer)	3	5
Ammonia (0.8% on water)	1.2	2
Activator Tetraethylene pentamine (TEP) (0.3% on rubber)	2.1	1.5
Formic acid	-	50
Sulphuric acid	40	-

The monomer emulsion is prepared by first mixing the monomer with cumene hydroperoxide or tertiary-butyl hydroperoxide (0.25% on rubber), oleic acid (1.0% on monomer) and then with water (½ volume) containing ammonia (0.8% on water). Vigorous agitation is necessary to form a good emulsion. Then the monomer emulsion is added slowly to the latex while stirring and the stirring is continued for 15 minutes. Tetra ethylene pentamine (TEP) solution is then added slowly to the mixture and stirring is continued for a further 10 minutes. The mixture is left for at least 18 hours to permit completion of polymerization; during this time, the latex is stirred as gently as possible.

The polymerization reaction is an exothermic reaction and the temperature of the mixture will rise during polymerization; the magnitude of the temperature rise depends on the scale of the preparation. Therefore, batches of 10 kg or more will require the use of reactor vessels fitted with a cooling water jacket. For very large-scale preparation, it is recommended to add monomer emulsion and the activator solution in two or three increments at hourly intervals. After the reaction, non-staining antioxidant dispersion is added prior to coagulation. The coagulum is washed and processed into crepe and dried. Alternatively MG rubber in powder form could be prepared by spray drying of the modified latex.

4.1 Properties and applications

Raw Heveaplus MG is stiff and non-tacky at ambient temperatures but it softens on heating and can be processed on conventional rubber machinery either alone or as a blend with normal grades of natural rubber. It can be compounded and vulcanized like natural rubber. This modified polymer is soluble in a variety of solvents and finds significant use in solution adhesives, particularly in primary coats or in pressure sensitive adhesives for binding rubber to materials such as polyvinyl chloride, textiles and leather. It is also used in hard impact resistant mouldings, in a vulcanized form.

4.2 Presentation

Heveaplus MG in crepe form is packed in bales of 45 to 50 kg weight according to grade and supplied in polythene-lined paper bags. The powder form is packed in 20 kg multiply paper bags and normally shipped in palletized units.

4.3 Measurements of the degree of polymerization

This is done by determining the total solids content of the NR latex before compounding and of the grafted latex after the completion of the reaction. The percentage polymerization is calculated using the following equation:

$$\% \text{ polymerization} = \frac{[BW - (AW_L + C + D)] \times 100}{M}$$

Where A - Fractional solids content of the latex
B - Fractional solids content of the reacted MG latex
C - Weight of oleic acid in the reaction mixture
D - Weight of tetraethylenepentamine in the reaction mixture
W - Total wet weight of reaction mixture
W_L - Weight of natural rubber latex in the reaction mixture
M - Weight of methylmethacrylate monomer in the reaction mixture

Heveaplus MG rubbers are used mainly in adhesives both in latex form and as solution. In solid form, these materials are used as light coloured, lightweight reinforcing agents for rubber in hard, impact resistant mouldings and in emulsion paints.

5. SUPERIOR PROCESSING (SP) RUBBER

Superior Processing (SP) rubber is the name given to a form of natural rubber, which has been prepared by coagulating an intimate mixture of vulcanized and unvulcanized latex. The appearance of the rubbers is quite similar to that of the normal grade of NR. The characteristic feature of this rubber is its reduced tendency to recover from deformation and therefore it is ideally suited for use in the manufacture of extruded and calendared products.

5.1 Vulcanization of latex

The chemicals required for vulcanization of latex have to be in the form of a dispersion in water to enable mixing with the latex. This is done by ball milling the chemicals with the addition of a small quantity of dispersing agent in the presence of water for 24-36 hours. The following formulation based on 100 parts of rubber have been recommended for the preparation of the dispersion.

Formulation for vulcanisation of latex

	phr
Sulphur	2.00
Zinc Oxide (ZnO)	0.75
Zinc diethyldithiocarbamate ZDC)	0.20
Mercaptobenzothiazole (MBT)	0.40
Dispersol LR (Dispersant)	0.02
Water	4.85
Total	8.22

Vulcanizing is done by first adding the required quantity of the dispersion of chemicals to the field latex which has been strained using a 40 mesh sieve and ammoniated at 0.3 percent and heating the mixture at 80 - 85° C for 1 hour, using live steam followed by maintaining this temperature for a further 2 hour period whilst stirring.

A simple method of testing complete vulcanization is to coagulate the treated latex with 10% formic acid. If the coagulum can be rolled between the fingers to give a continuous coagulum it is considered that the vulcanization is incomplete. On the other hand if the resultant coagulum is a powdery dispersion of rubber, then it is considered as vulcanized. After the reaction time the latex is allowed to cool and its total solids content is determined before blending with unvulcanized latex.

5.2 Grades of SP rubbers

SP rubbers are manufactured and marketed as Superior Processing Ribbed Smoked Sheets (SP/RSS), Superior Processing Air Dried Sheets (SP/ADS), Superior Processing Crepe (SP Crepe) and as masterbatches (PA 80 and PA 57). The first four grades contain 20 percent vulcanized and 80 percent unvulcanized rubber. PA 57, which is an oil-extended version of PA 80 consists of 70 percent PA 80 and 30 percent of non-staining process oil.

5.2.1 Manufacture of SP/RSS, SP/ADS and SP/ pale crepe rubber

In the preparation of different grades of SP rubbers, fresh field latex is diluted to 20 percent DRC and thoroughly blended with vulcanized latex which has also been diluted in the ratio of 4 parts of unvulcanized latex to 1 part of vulcanized latex (based on rubber content). Vulcanized latex is diluted to 12.5% total solids in the production of SP/RSS and SP/ADS and 20% total solids for the production of SP crepe. The thoroughly blended mixture is then sieved, coagulated with 2% formic acid and processed using the same procedure as for the normal grades of sheet and crepe rubber.

5.2.2 Manufacture of SP brown crepe

SP Brown Crepe is prepared by mixing the masterbatch in the form of undried crumbs containing 80% vulcanized particles with wet scrap during milling operations to give the usual 20% content of vulcanized particles. After mixing, the rubber is processed as estate brown crepe.

5.2.3 Manufacture of PA 80 and PA 57 masterbatches

Concentrated masterbatches could also be produced to form a superior processing rubber which would allow the consumer to obtain any desired degree of superior processing character in almost any type of rubber, natural and synthetic. These masterbatches are called processing aid 80 or PA80 and processing aid 57 or PA57 which is an oil extended version of PA80.

The weight proportions of raw and vulcanized rubbers used are as follows;

PA 80-	Vulcanized rubber	80 parts
	Raw rubber	20 parts
PA 57	Vulcanized rubber	80 parts
	Raw rubber	20 parts
	Process oil	40 parts

PA 80 is prepared by mixing 4 parts of vulcanized latex with 20% solids content with one part (based on DRC) of unvulcanized field latex as quickly as possible and coagulating the mixture using 5% sulphuric acid. The serum is removed and the coagulum is soaked in clean water for 30 minutes and crumbled either by passing through lightly grooved crepe rollers or similar rollers used in the production of block rubber. The crumbs obtained are again soaked in water for 1 hour and then dried for 4-5 hours at 70 °C in a tunnel drier.

In the production of PA 57, non-staining, non-discoloring oil is added as a stable emulsion to the blended latex containing the correct proportion of unvulcanized and vulcanized rubber particles. The processing is the same as that for PA 80.

5.3 Testing of SP rubbers

The following formulation has been used for the preparation of the compound for testing the extrusion swell. Here the base polymer contains 20% vulcanized and 80% unvulcanized rubber (SP 20 rubber) or is blended with a normal grade of rubber (1:3 for PA 80) to obtain the same composition.

SP 20 rubber	100.0
HAF black	50.0
Zinc oxide (ZnO)	5.0
Stearic acid	4.0
Sulphur	2.5
Pine tar	3.0
Accelerator (CBS)	0.6

The extrusion swell is measured using a Macklow Smith extrusion plastimeter. For SP grades PA 80, PA 57 and grades containing 20% vulcanized rubber content, the maximum extrusion swell should be less than 12.7. For PA 80 a maximum of 80 Mooney units for viscosity value has also been specified. The oil content of PA 57 is measured by acetone extract determination and is included in the specifications.

6. THERMOPLASTIC NATURAL RUBBER (TPNR)

Thermoplastic rubbers could be processed like a thermoplastic at processing temperature and show characteristics of a vulcanized rubber at service temperature. Thermoplastic rubber produced by blending NR with polyolefines (TPNR) shows considerable promise for commercial exploitation.

TPNR soft and hard grades could be used for the production of moulded automotive components like car bumpers, rail pads, extrusion of pipes and for the manufacture of general moulded goods including plugs and gaskets. The essential details of the production methods of these two types are as follows:

These materials are prepared by mixing natural rubber with polyolefin resins (in ratio of NR 40-60% with polyolefin resin 60 - 40% using standard mixing machines such as Banbury, or an intermix. Control of the temperature of the batch is important. Starting with a warm machine (80^{0}C - 120°C) mixing soon raises the temperature to the melting point of the resin (135°C for high-density polyethylene, 165°C for polypropylene). High speed mixing is advantageous but care should be taken not to allow the temperature to rise higher than 200°C for more than a few minutes, to avoid possible degradation of natural rubber,

A typical mixing cycle in a BR Banbury with rotor speed 116 rpm is:

0 Minutes - Add natural rubber, antioxidants, polyolefin and filler (if used)
5 Minutes - Dump

An organic peroxide or any other cross-linking reagent for the rubber may be added during the preparation. In this case the following mixing cycle is adopted:

0 Minutes - Add natural rubber, polyolefin and filler (if used)
2-3 Minutes - Add cross-linking agent: quantity necessary for partial cross linking of natural rubber
5 Minutes - Add antioxidant
6 Minutes - Dump

The mixed batch, while still hot, can be shredded on a rotary type of cutter to the desired size. A little partitioning agent can be added to prevent re-agglomerisation in the case of softer grades.

TPNR blends in granular form can be used directly for further processing by extrusion or injection moulding techniques. Possible uses of TPNR blends are in automotive components *e.g.* car bumpers, rail pads, tank lining and for general moulded goods such as electric plugs, closures and gaskets to name a few.

7. OIL EXTENDED NATURAL RUBBER (OENR)

Mineral oils are commonly used in rubber compounding to improve processability of the rubber and to facilitate easy incorporation of fillers, especially carbon black. The oil extension of rubbers by processing oils allows the rubber manufacturer to produce low cost compounds for use in the rubber products industry. When oil is incorporated at 20% or more it is referred to as Oil Extended Natural Rubber (OENR). Considerable savings in compounding of NR-based articles could be achieved by oil extension, without loss in technical properties such as resistance to abrasion, compression set, flex cracking and ozone cracking, provided attention is paid to curing system. OENR tyres can have increased skid resistance on wet roads.

Early attempts to extend conventional forms of NR such as sheet and crepe with oil failed, owing to the softening effect caused by the oil, which made these forms of rubber unsuitable for smoking in a smoke house, or hot air drying in a crepe drying tower. Oil extended rubber in the form of crumbs could be dried in trays; this has made possible commercial production of oil extended natural rubber (OENR) in the form of block rubbers. One of the outstanding properties of OENR is its superior skid resistance on wet icy roads, compared to all other forms of natural and synthetic rubbers and now OENR is gaining a major and important outlet in treads of winter tyres.

Naphthenic and aromatic types of oils are the preferred types of oil: 20 - 40% of oil could be incorporated into the rubber without any practical difficulty in the production of OENR.

7.1 Processing methods

Oil extension of natural rubber could be carried out both in the latex and dry rubber stages.

7.1.1 Latex methods

Oil in the form of aqueous emulsion is added to latex at pH 8-8.5, mixed and the mixture coagulated using an acid. The coagulum is then processed into block rubber using the standard procedure. The main disadvantages of this method are the high cost of chemicals and longer drying time. This method is now used only for the production of PA 57.

7.1.2 Dry rubber method

Dry mixing of oil with rubber can be done by soaking or by extrusion methods. In the Kualakep soaking process the hot crumb and oil are mixed together in a Zblade mixer for 5 - 10 minutes and the rubber is allowed to absorb the remainder of the oil. Finally the extended rubber is blended on a two-roll mill, baled and packed. The Socfin soaking method involves soaking of wet crumbs in oil followed by steaming for 10 - 12 minutes. Then the extended rubber is dried at low temperatures in shallow beds.

8. POWDERED/GRANULAR RUBBER

Natural rubber in powdered or granular form can be processed in an automatic process line and the demand for these forms is on the increase. Natural rubber in free-flowing powdered or granular form has certain advantages over the conventional forms of rubber in processing.

Some of these advantages are:

- The elimination of bale cutting operations
- Shorter mixing cycle
- Less power consumption
- Less capital investment for plant
- Possibility of direct feed to the extruder
- Easier control in the factory

Powdered/granulated natural rubber has been prepared by the following routes:

- By granulation of solid natural rubber using rotary cutters, adding partitioning agents.
- By spray drying of latex, adding partitioning agents
- By encapsulation of NR particles using other polymeric materials such as starch xanthate, polyvalent metal (*e.g.* Al^{3+}), salts of carboxylic polymers such as carboxyl cellulose, acrylic and methacrylic acid polymers, alginates *etc.*

8.1 Methods of preparation of powdered /granulated natural rubber

8.1.1 Mechanical granulation

Although particulate forms of natural rubber are made mainly by granulation processes in consuming countries, very little information is available on this subject. This lack of information prompted investigation into the process of granulation of NR, to remain in the present market and to develop new markets for powdered forms of NR.

Granulation of natural rubber could be done on a granulator, which has a steel rotor with rotating knives (at 1500 rpm). The knives have to be set as close as possible (*e.g.* close enough to cut paper about 0.05 -0.1 mm thick). For effective granulation, it is necessary to cool the rotor and casing by passing cold water and to feed the machine at the correct rate (0.5 kg rubber/1.5-2 min intervals) to avoid overfeeding which results in massing up of rubber causing the cutter to go into a mastication action rather than a cutting one. It is necessary to add about 5% partitioning agent *e.g.* talc, finely divided silica, precipitated calcium carbonate or zinc oxide, *etc.*, during the process.

A cold draft of air is allowed to pass through the granulator which assists cooling and transports rubber granules pneumatically from the cutting chamber housed at a lower elevation, to the top of a cyclone which separates rubber, talc (partitioning agent) and air. Air flow rates can be adjusted by pulleys on the fans located between the granulator and the cyclone, so that it separates the talc from the useful product, allowing rubber to drop into an open bin, while the dust collector sucks away the free talc.

It has been found that the particle size distribution depends on the screen size and the type of granulator and can conveniently yield NR particles in the range of about 4-16 mm with a small percentage of smaller particles.

8.1.2 Spray drying techniques

Harrison and Crossfield Research Laboratories, UK, in the late 1960s developed a process for the production of a powdered form of natural rubber using the spray drying technique. Following customers' assessment of the UK - produced powdered natural rubber a commercial plant was set up in Malaysia in 1975 which has a production capacity of 250 - 300 tons per month.

The first step in this process involves creaming of ammoniated field latex using sodium alginate as the creaming agent which has been treated with laurate soaps and hydroxylamine neutral sulphate for mechanical and viscosity stabilizing. A DRC of 55 % could be obtained by creaming for 14-36 hours. The Zahn cup No 2 viscosity of the creamed latex should be at least 23 seconds for spray drying.

The second step is the spray drying process of the treated creamed latex. This involves atomizing the rubber latex in a stream of hot gas, which permits rapid heat and mass transfer. Atomisation is effected by controlled feeding of the creamed latex on to a 37 cm inverted bowl disc revolving at a speed of 6,400 rpm. Air is heated to about 200^0C and Ultrasil VN 3 is introduced into this prior to passing into the spray chamber. The rate of drying is measured in seconds and microseconds under these conditions. A rotating scraper arm sweeps down the product which deposits on the chamber wall on to a conveyor at the chamber bottom. The fine Ultrasil VN 3 - rich particles are carried away in the effluent air which passes through a cyclone to effect primary separation of the coarse particles. Recovery of the very fine particles is achieved in a bag filler or dust collector.

8.1.3 Encapsulation

Particle encapsulation was investigated in the 1920s for the preparation of powdered natural rubber and reasonably satisfactory particulate rubber was obtained using a very small proportion of ethyl methyl cellulose and a suitable caseinate as encapsulating agents. Due to increased demand for this rubber in particulate form for use in automatic processing machines, investigations have been carried out to find suitable encapsulating agents for the preparation of powdered and granular forms of natural rubber. Several polymers such as starch zanthate, carboxymethylcellulose, acrylic acid and methacrylic acid based polymers, styrene-maleic anhydride polymers and alginates have been used as encapsulating agents. Surface halogenation of NR in wet crumb form is being tried out at the Rubber Research Institute of Malaysia (RRIM) to reduce the surface tack, to prevent or reduce re-agglomeration.

Though NR in particulate form has been prepared by several methods, still the problem of re-agglomeration exists and a completely satisfactory answer has not been found. Further, the transportation of rubber in particulate form requires careful packaging and the freight or transport charges are higher due to the low bulk density of the materials, except when a container is used.

9. DEPOLYMERIZED NATURAL RUBBER/LIQUID NATURAL RUBBER

Depolymerized Natural Rubber is an important derivative, which can be produced by degradation of natural rubber using different processes and techniques. Depolymerized rubber can supplement the wide range of natural and synthetic elastomers currently on the market, mainly in the adhesive industry and in ebonite manufacture as a non-extractable, non-toxic material and vulcanizable processing aid in natural rubber compounding.

Incorporation of depolymerized rubber into the rubber formulations to replace processing oils can significantly reduce the viscosity of the raw rubber blends whilst the vulcanizates show improvements in abrasion resistance and physical properties due to its vulcanizable characteristics.

Commercial production of liquid natural rubber dates back to the early 20th century. Different grades of varying viscosity of liquid natural rubber are being produced by Lorival Ltd, UK and Hardman Inc., USA in small quantities. These rubbers are produced by depolymerization of natural rubber using mechano-chemical methods. They are suitable as casting compounds and produce softer types of vulcanizates which have very much inferior physical properties compared to the vulcanizates obtained from solid rubber. These materials are referred to as first generation liquid rubbers.

Presently, there are several synthetic materials which are referred to as second generation liquid rubbers, as they could be chain-extended and cross-linked to obtain vulcanizates with better physical properties. Efforts have been made to produce functional group-terminated liquid natural rubber in recent years. Carbonyl group-terminated liquid natural rubber could be produced by a photochemical process, using nitrobenzene as the chain degradant with NR in solution. They were able to cross-link and chain-extend these materials but the work has been discontinued as the required range of physical properties could not be obtained. Using nitrobenzene as the reagent, RRISL scientists have shown that it is possible to effect a reduction in the molecular weight of natural rubber in the solid state by exposing it to sunlight. French workers have developed a process for the preparation of functional group-terminated liquid natural rubber in the latex stage using phenyl hydrazine as the reagent. The liquid rubber obtained has been found to contain terminal hydrazone groups which can be oxidised under controlled conditions to a carboxylic acid group using a hypochlorite or hypobromite in alkaline medium.

The properties of all types of liquid rubber, including the synthetic, after curing do not still match those of the solid rubbers and therefore they cannot be considered as alternative materials to solid rubber. Liquid rubber find major use in adhesives, cold vulcanising mixtures in the manufacture of flexible casts and as cast binders in rocket propellers and coatings.

10. POSITEX

By reversing the charge of the rubber particles certain properties of latex can be modified. Positex is a value added grade of NR where the rubber particles are positively charged, highly stable and the solids content is as high as 60%. It is a good binder for textiles and also can be mixed with bitumen and cement to improve performance of the application.

Positex may be prepared by the addition of an excess of a quarternary ammonium cationic surface-active substance to negatively charged natural rubber latex. If a sufficient amount of the cationic surface-active agent is added, then adsorption occurs to such an extent that the charge on the particles is changed from negative to positive. Typical cationic surface-active substances which are suitable for the preparation of positex include cetyltrimethyl-ammonium bromide and cetylpyridinieum bromide. It is necessary to make the addition of excess cationic substrate rapidly; otherwise the latex may be irreversibly flocculated. An alternative procedure is to pour the latex into the solution of cationic surface-active agent, so that an excess of the latter is inevitably ensured.

11. CYCLISED RUBBER

Cyclised rubber (>60% cyclisation) is a hard, brittle, thermoplastic derivative of NR, obtained by treating NR with acidic catalysts such as para-toluene sulphonic acid, concentrated sulphuric acid and Lewis acid catalysts (*e.g.* stannic chloride). Cyclised rubber can be prepared from rubber in solutions, solid rubber or from latex.

11.1 Methods of preparation of cyclised rubber

11.1.1 Solution method

Solution stage cyclisation is best carried out in the presence of stannic chloride or using concentrated sulphuric acid in excess as the cyclising agent. In the process where stannic chloride is used, well-masticated rubber in aromatic hydrocarbon solvents, such as benzene or toluene, is treated with 3-5 phr of stannic chloride (anhydrous) at 80°C for about 4-5 hours, until the viscosity drops suddenly to a lower value. At this stage the reaction is arrested by adding a small quantity of water or alcohol. The solid cyclised rubber is obtained from the solution by steam distillation, followed by drying. The dried material is then milled to effect reduction in the molecular weight and is commercially available as a coarse powder or chips. This is suitable for use as a binder in anticorrosive paints and printing inks.

11.1.2 Latex method

Latex stage cyclisation is effected by treating suitably stabilized centrifuged latex with concentrated sulphuric acid added at 70% w/w on the serum over a period of about 2 hours at 100°C. A non-ionic soap such as vulcastab LW or a cationic soap such as cetyl trimethyl ammonium bromide is suitable as a stabilizer for this purpose. The addition of concentrated sulphuric acid has to be done slowly and carefully at the early stages. The cyclisation reaction is also highly exothermic and great care should be exercised in maintaining the temperature at the desired range.

On completion of the reaction, the cyclised rubber latex can be coagulated by pouring into a substantial quantity of boiling water. This can also be used for the preparation of cyclised rubber: NR 50:50 masterbatches.

11.1.3 Cyclised rubber masterbatches

Cyclised rubber latex can be blended with an equal amount of suitably stabilised field latex for the preparation of masterbatches. Cyclised rubber& NR 50:50 masterbatch can be prepared by mixing equal amounts of cyclised and uncyclised latex and coagulating the mixture by pouring into boiling water. The coagulum so obtained is washed, creped and dried in the usual manner. This masterbatch is suitable for use as a lightweight reinforcing filler for rubber compounds.

11.1.4 Solid rubber method

Earlier, cyclised rubber was produced by the solid rubber method by mixing NR with 10 phr para-toluene sulphonic acid, followed by heating the mixture in an oven for about half an hour at about 120°C. It is possible to effect auto-cyclisation of papain-coagulated natural rubber using 10phr of para-toluene sulphonic acid with subsequent milling to make rubber crumbs of cyclized rubber. Milling is continued until rubber crumbles into pieces (30 - 45 minutes) and the rubber is taken out from the mill at this stage, folded and kept for autocyclization to occur. The reaction is highly exothermic and results in the formation of a molten mass, which solidifies to a dark brownish black, brittle resin on cooling. The solid resin can be easily powdered on a grooved two-roll mill. The excess acid present is either neutralized by adding the required quantity of calcium oxide or by washing with water followed by dilute alkali, again with water and drying.

This resin is found to be suitable for use as reinforcing filler for rubber. However, it is necessary to incorporate this as a masterbatch in NR for effective reinforcement due to higher dispersibility. By adding a small amount of peptiser such as xylyl mercaptan or tolyl mercaptan (0.5, phr), either during the preparation of papain-coagulated rubber or during the mixing process It is possible to prepare a grade of cyclised rubber with enhanced solubility in solvents for preperation of cyclised rubber solutions for applications such as rubber adhesives.

12. CHLORINATED RUBBER

The method of preparation of chlorinated rubber used in commercial production is the direct chlorination of rubber in an inert solvent *e.g.* carbon tetrachloride at temperatures around 80^{0}C. In order to avoid gelation during chlorination and to obtain products of a sufficiently low viscosity to be practically useful, the rubber is usually broken down considerably, normally by milling, before making the rubber solution.

Chlorinated rubber could also be prepared directly from latex. It is accomplished at room temperatures around 20-30°C, provided that the latex is first stabilized by means of a non-ionic stabilizer or by means of a combination of a non- ionic and a cationic stabilizer. A strongly acidic medium is distinctly advantageous to avoid incidental addition of hypochlorous acid. This can be achieved if the serum is brought to an acid concentration of 8N with conc. HCl. A chlorate solution is added to latex acidified with HCl, and the chlorine generated *in situ* reacts rapidly with the rubber. The preparation of chlorinated rubber from latex has not reached the scale of commercial production. This method usually gives a rather insoluble product and hence NR molecules in the latex medium has to be degraded prior to cholorination, if soluble products of commercial interest are to be obtained.

The commercial production of soluble chlorinated rubber from suitably stabilized field latex would be of great value to the natural rubber-producing countries if such a soluble product could be obtained from latex medium rather than the solution process. Heat development during the production of chlorinated rubber is also very much less in the latex process than the solution process which is a definite advantage of latex medium of chlorination..

A soluble chlorinated rubber is completely soluble in the conventional solvents used in the paint and the lacquer industry, *e.g.* aromatic hydrocarbons, chlorinated hydrocarbons, esters and ketones. The production of a high quality chlorinated rubber requires relatively high capital invesment and special know-how.

12.1 Uses of chlorinated rubber

The applications of chlorinated rubber are in protective coatings especially where resistance to chemicals or corrosive atmospheres is required; e.g traffic paints on roads, adhesives, printing inks, paper coating and textile finishes. Chlorinated rubber paint can be successfully applied on metal, concrete or asbestos cement by brushing or by spraying and is used on applications such as finishes on drinking water tanks, swimming pool finishes and in floor finishes. Contact adhesives can be made from chlorinated rubber, the ingredients being natural rubber, chlorinated rubber, rosin, solvent, magnesium oxide, zinc oxide and plasticiser. Chlorinated rubber can also be used in emulsion paints. Satisfactory emulsions can be made out of chlorinated rubber, by dissolving chlorinated rubber in toluene, introducing it into water along with emulsifying agents and emulsifying with a high-speed stirrer. The composition is then ground with an aqueous pigment paste. Such emulsions can be freely thinned with water and they have a good shelf life. Finishes of these emulsions yield satisfactory results on concrete, asbestos cement or asphalt surfaces.

13. EPOXIDIZED NATURAL RUBBER (ENR)

Epoxidized Natural Rubber is a modified form of NR, which has improved characteristic properties compared to NR. The epoxidation reaction has been found to alter the glass transition temperature (approximately 1% per mole) consequently reducing the resilience, improving oil resistance and reducing gas permeability. Because of these special characteristics, ENR could be compared with certain synthetic rubbers. (*e.g.* 50% ENR is comparable in oil resistance to a certain grades of nitrile rubber). Its air permeability properties are similar to those of butyl rubber. High damping characteristics of ENR make it suitable for many engineering applications. Two types of ENR are commercially available in the market, *i.e.* ENR 25 and ENR 50.

Two methods are being adopted for preparation of ENR, which start from solid NR and NR latex:

(a) Solution method
(b) Latex method

In both methods a peracid is used as the epoxidizing agent, which could either be used as a preformed peracid or generated *in-situ*.

(a) **Preformed peracid**: This is a two-stage technique, where hydrogen peroxide and an organic acid such as formic or acetic acid are reacted to form peracid as the initial step. This is added to the latex drop-wise in order to initiate the epoxidation.

(b) ***In-situ* generation of peracid:** Peracids are extremely active species but owing to their instability, preparation of it *in-situ* is preferable. This is the preferred route in commercial application.

13.1 Methods of preparation of ENR

13.1.1 Solution method

Method 1: The purified solid NR is dissolved in $CHCl_3$ and deoxygenated by bubbling dry N_2. Chloroperbenzoic acid is then added and stirred for 1 hr at 20°C. The resultant epoxidised NR solution is precipitated with methanol, filtered, washed with water and dried at 34°C.

Method 2: purified NR is dissolved in benzene to prepare a 1.5v/w solution and deoxygenated by bubbling dry N_2. 0.7 ml H_2O_2 and 0.07 ml of 98% formic acid is added and stirred for 24 hr at 35-40°C. The mixture is precipitated with methanol, filtered, washed with water and dried at 34°C.

13.1.2 Latex method

NR latex having 60% DRC is diluted with water to reduce the DRC to 30%. After adding non-ionic stabilizer, formic acid and hydrogen peroxide are added drop-wise at 50°C with continuous stirring. The ENR sample is coagulated with 98% ethanol and dried at room temperature for three days.

Chapter 8

Chemicals used in raw rubber manufacture[*]

U.N. Ratnayake

1. INTRODUCTION

Chemicals are used in raw rubber manufacture for various purposes at different stages of processing. The chemicals used in raw rubber manufacture can be categorized under

1. Preservatives
2. Chemicals used to prevent enzymatic discolouration
3. Bleaching agents
4. Coagulants.

2. PRESERVATIVES

2.1 Ammonia and ammonium hydroxide

Ammonia was the first preservative used in the raw rubber industry and is still the best preservative for latex. It is available in both gaseous and liquid form.

Chemical formula

NH_3 (gas) or NH_4OH (ammonium hydroxide in aqueous solution)

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[*] Adapted from "A Handbook of Rubber Culture and Processing", 1983

Purity

Available as pure liquified ammonia gas in steel cylinders containing 68 kg of ammonia approximately, or as 25% - 35% concentrated aqueous solutions.

Properties

i. Clear, colourless, liquid/gas with a strong pungent smell
ii. Molecular weight: NH_3 - 17, NH_4OH - 35
iii. Storage stability: Ammonia solution should be kept in tightly closed bottles. Ammonia gas escapes and the solution becomes weak if left open
iv. Solubility: Gas is easily soluble in water.

Toxicity and handling precautions

Corrosive. Avoid breathing the vapour. Bottles of concentrated ammonia intended to be opened on the following day should be left to cool by immersing in cold water.

Usage and action

Ammonia is used as an anticoagulant only in the manufacture of RSS. It is not suitable as an anticoagulant in the manufacture of pale crepe because it may cause discolouration of rubber. It inhibits the growth of bacteria, neutralizes any acids formed and the pH is increased in latex. Ammonia is extensively used in concentrated latex manufacture as a long-term preservative.

2.2 Sodium sulphite

Mainly used as a latex anticoagulant: the best anticoagulant for latex crepe manufacture.

Chemical formula

$Na_2SO_3 . 7H_2O$.

Purity

Fresh stuff is 96% pure. However, it decomposes fast when exposed to air, hence effectiveness (strength) decreases continuously, unless it is kept in air-tight containers.

Properties

i. Fine, crystalline, white powder
ii. Molecular weight: 252.15
iii. Storage stability: fairly unstable under tropical conditions and should be kept in a cool place in an air-tight container. Solution is highly unstable
vi. Solubility – easily soluble in water

Toxicity and handling precautions

Non-toxic

Usage and action

Widely used anticoagulant in raw rubber manufacturing processes. It inhibits the bacterial growth and prevents the formation of volatile fatty acids such as acetic and formic acids. Due to its alkaline nature it can also neutralize the acids already developed in latex. Stock solution must be freshly prepared and kept in a tightly closed bottle until use.

2.3 Sodium carbonate

Other names

Washing soda

Chemical formula

$Na_2CO_3 . 10H_2O$.

Purity

Dry powder is 96 to 98.0% pure.

Properties

i. White crystalline powder
ii. Molecular weight: 286.14
iii. Storage stability: should preferably be kept away from acids. Stable compound in both liquid and solid phase.
iv. Solubility: Readily soluble in water.

Toxicity and handling precautions

Irritating, avoid breathing the dust.

Usage and action

When used as an anticoagulant, there is a risk of bubble formation and therefore it is not suitable in sheet rubber manufacture. Due to the alkaline nature of Na_2CO_3 the solution neutralizes the acids developed in latex. It is very rarely used as an anticoagulant.

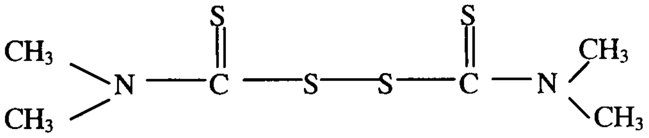
2.4 Tetramethylthiuram disulphide/Zinc oxide (TMTD/ZnO)

Used in the manufacture of LA centrifuged latex as a secondary preservative with ammonia.

Chemical formula

TMTD – $[(CH_3)_2 NCS]_2S_2$
Zinc Oxide - ZnO

Chemical structure



Purity

TMTD - 95%
ZnO - Above 95%

Properties

i. TMTD: white crystalline powder with characteristic odour, ZnO - white or greyish powder, odourless
ii. Molecular weight: TMTD – 178, ZnO – 81.38
iii. Solubility: both insoluble in water, TMTD soluble in alcohol, ZnO soluble in acids and alkaline solutions

Toxicity and handling precautions

TMTD : Toxic by ingestion and inhalation, irritant to skin and eyes
ZnO : Avoid inhalation of dust .

Usage and action

TMTD/ZnO is added as a 25% dispersion to latex in the field as well as in the factory. It acts as a strong bactericide in combination with ammonia.

3. CHEMICALS USED TO PREVENT ENZYAMATIC DISCOLOURATION

3.1 Sodium metabisulphite and Sodium bisulphite

Used to prevent enzymatic discolouration mainly in crepe rubber manufacture.

Chemical formula

i. Sodium metabisulphite - $Na_2S_2O_5$
ii. Sodium bisulphite - $NaHSO_3$

Purity

Should not be less than 95%.

Properties

i. Fine white crystalline powder. Strong smell of sulphur dioxide
ii. Molecular weight
Sodium metabisulphite - 190.09
Sodium bisulphite - 104.05

iii. Storage stability : Should be kept in closed vessels which should not be left open unnecessarily. Hard lumps which cannot be crushed with fingers must not be used. If completely hardened, the chemical should be discarded

iv. Solubility : Readily soluble in water. When dissolved in water, sodium metabisulphite decomposes to sodium bisulphite.

Toxicity and handling precautions

Contains 60% sulphur dioxide, hence mammalian toxicity is high and human beings should not be exposed to the gases evolved.

Usage and action

Sodium metabisulphite and sodium bisulphite reduce enzymatic darkening in latex crepe manufacture by acting as reducing agents, thereby removing the O_2 from the medium preventing oxidation of phenolic substances present in latex as non rubbers.

4. BLEACHING AGENTS

The only bleaching agent used in the industry is sodium para-toluene thiophenate which is an aromatic mercaptan. It bleaches carotenoid pigments which remain after fractionation in the manufacturing process of light coloured pale crepe.

Chemical name

Sodium para-toluenethiophenate.

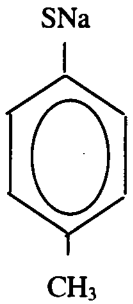
Commercial names

Nexobleech, RPA4, Poly bleach and Rupepa.

Chemical formula

$C_7H_7S\ Na$

Chemical structure



Properties

i. Toluene - para – thiol is a white to yellow fused solid and sodium salt of thiol (Sodium para-toluene thiophenate) is a clear syrupy liquid with a few needle-type crystals floating on the surface
ii. Specific gravity: 1.19
iii. Melting point: over 280 °C
iv. Storage stability: Should preferably be kept away from fire and excessive heat. Once the container is opened for removal of part of the chemical, it should be tightly closed immediately to prevent crystal formation *i.e* conversion of sodium salt back to thiol which usually appears as crystals floating on the liquid surface. If many crystals are present, effective thiol content must be checked before use.
v. Solubility: soluble in water.

Toxicity and handling precautions

Toxic, but if adequate precautions are taken, there should be no serious problem in handling this chemical. Excessive inhalation of the vapour or skin contact should be avoided.

Usage and action

Active ingredient of the chemical reacts with yellow pigments (caratenoids) in latex to give colourless compounds. It must be added fresh into latex. Addition of this chemical in excess does not further improve the colour of laces, but may cause storage softening. This effect also results in deterioration of colour and imparts tackiness to rubber.

5. COAGULANTS

5.1 Formic acid

This is the preferred coagulant for RSS and pale crepe manufacture.

Chemical formula

HCOOH

Purity

Available as 85% solution.

Properties

i. Clear, colourless liquid with a pungent odour and has antiseptic properties.
ii. Molecular weight: 46.0.
iii. Specific gravity: 1.185.
iv. Storage stability: Stable chemical.
v. Solubility: Miscible with water, alcohol, ether and glycerol.

Toxicity and handling precautions

Corrosive. Do not breathe vapour. It is a strong irritant to skin and tissues.

Usage and action

Weak acid, but stronger than acetic acid. NR latex is destabilized by the addition of formic acid and therefore latex coagulates. It should be used as a 1% solution in water.

5.2 Acetic acid

Glacial acetic acid is the pure compound (99.8% purity) as distinguished from the usual aqueous solution known as acetic acid. Not recommended for latex crepe.

Chemical formula

$CH_3\,COOH$

Purity

Available as 85% (acetic acid) solution

Properties

i. Weak acid, clear colourless liquid and has no antiseptic properties.
ii. Molecular weight: 60.5
.iii. Solubility: Soluble in water.

Toxicity and handling precautions

Corrosive. Harmful to breathe, concentrated acid causes burns if it comes in contact with the skin.

Usage and action

Acetic acid is a weak acid compared to formic acid and its concentration should be double that of formic acid to have the same effect and unlike formic acid, it does not have antiseptic properties.

5.3 Oxalic acid

Used mainly as a coagulant to prevent storage discolouration, only in the manufacture of sole crepe under extremely severe conditions of discolouration.

Chemical formula

$C_2H_2O_4.\ 2H_2O$

Purity

98%

Properties

i. Form: white crystalline solid
ii. Molecular weight: 126.07
iii. Solubility: more soluble in warm water than in cold.

Toxicity and handling precautions

It is toxic if inhaled or in contact with the skin. Avoid contact with skin and eyes.

Usage and action

By making complexes with polyvalent metal ions, oxalic acid prevents storage discolouration. Oxalic acid alone or oxalic acid with formic acid are recommended for sole crepe manufacture if hardness of water is high. It has a corrosive action on iron. Therefore rollers should be thoroughly washed with water after milling of oxalic acid-coagulated rubber.

Oxalic acid also acts as a good enzyme inhibitor and therefore if latex is coagulated with oxalic acid, the dosage of sodium bisulphite incorporated into latex for prevention of enzymatic discolouration could be reduced.

6. ANCILLARY CHEMICALS

6.1 Lauric acid

It is used in manufacture of centrifuged latex.

Chemical formula

$CH_3\,(CH_2)_{10}\,COOH$

Purity

98%

Properties

(i). Colourless needles
(ii). Molecular weight: 200
(iii). Solubility: not readily soluble in water

Toxicity and handling precautions

Non-toxic.

Usage and action

It dissolves in hot water and ammonium laurate is prepared by mixing with ammonia. Ammonium laurate is added as a 10% solution to the latex. Half of the required solution is added before centrifuging and the other half is added after centrifugation. It improves the mechanical stability of the centrifuged latex.

6.2 Di ammonium hydrogen phosphate (DAHP)

It is used in the manufacture of centrifuged latex.

Chemical formula

$(NH_4)_2 HPO_4$

Purity

97%

Properties

i. White crystals or powder
ii. Molecular weight: 132
iii. Solubility: Soluble in water

Toxicity and handling precautions

Toxicity is very low.

Usage and action

This can also be prepared by mixing of ammonia and phosphoric acid. It is used to remove magnesium in latex. Mg^{2+} in latex is precipitated as magnesium ammonium phosphate, usually known as sludge, at the bottom of the latex-collecting tanks.

7. GENERAL GUIDELINES FOR THE USE OF CHEMICALS EFFECTIVELY IN THE MANUFACTURING PROCESS OF RAW RUBBER

i. Give careful attention to the correct storage of chemicals
ii. Avoid using deteriorated chemicals
iii. Add correct dosage as dilute solutions in recommended concentrations
iv. Avoid adding excess of chemicals beyond the recommended levels
v. Avoid using solutions kept for several days
vi. Label the chemicals properly.
vii. Read and follow the instructions given with chemicals
viii. Purchase chemicals only from reputed or accredited suppliers
ix. If there is any doubt, make early arrangements to get the chemicals tested at RRISL.

Chapter 9

Rubber products manufacture

N.M.V. Kalyani Liyanage

1. Introduction
2. Latex-based products
   - 2.1 Latex dipping
     - 2.1.1. Dipping techniques
   - 2.2 Latex foam
   - 2.3 Latex thread
   - 2.4 Latex castings
     - 2.4.1 Preparation of hollow moulds
     - 2.4.2 Casting in plaster of Paris moulds
     - 2.4.3 Heat sensitive casting
3. Dry rubber-based products
   - 3.1 Mixing
   - 3.2 Shaping
     - 3.2.1 Compression moulding
     - 3.2.2 Extrusion
     - 3.2.3 Calandering
     - 3.2.4 Spreading
   - 3.3 Vulcanization

1. INTRODUCTION

Natural Rubber (NR) either in latex form or in dry rubber form is used to make a wide variety of products ranging from toy balloons to automobile tyres. The major product groups accounting for the largest share of NR consumption in Sri Lanka are tyres and tubes, tyre retreads, footwear including soles and heels, household gloves, foam rubber, rubberised coir, rubber bands, hospital sheeting and many moulded automotive parts. Moulded products including solid tyres, footwear and household gloves are the main export products. All these rubber products can be classified into two groups depending on the nature of the starting raw material, *i.e.*

i Latex-based products   ii Dry rubber-based products

2. LATEX-BASED PRODUCTS

As the name implies the latex-based products are manufactured starting from concentrated latex. There are several advantages of making rubber products from latex. The value addition is higher, latex products generally contain high rubber contents and also less energy is required to manufacture latex-based products. Many different production techniques are used to convert natural rubber latex into products. However, the following can be identified as the most widely used production techniques:

a. Dipping
b. Foaming
c. Extrusion
d. Casting

The products made using the above techniques are called dipped products, latex foam products, extruded products and cast products respectively. In addition to these, there are other products such as rubberised coir and various adhesives which also contain a considerable proportion of natural rubber.

2.1 Latex dipping

The latex dipping process consists of immersion of an appropriately shaped former into a vulcanisable latex mix followed by withdrawal of the former (Plate 9.1c) and drying and vulcanisation of the deposit (Plate 9.1d). The wide range of goods produced by this type of process includes household, medical and industrial gloves, bottle teats and soothers, prophylactics, catheters, balloons and football bladders, *etc.*

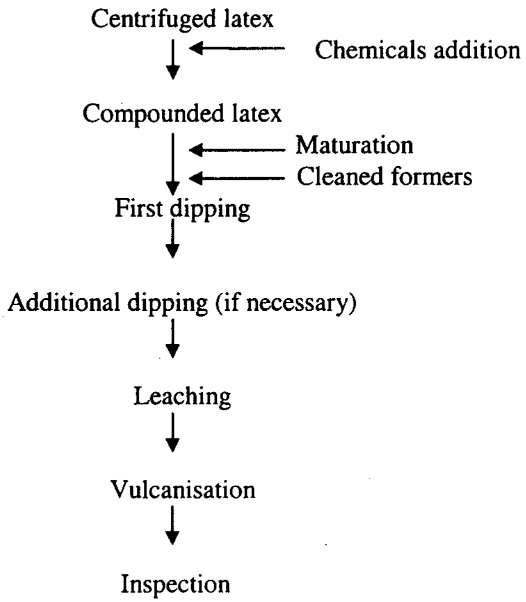
2.1.1 Dipping techniques

Three dipping techniques for obtaining a deposit on the former are commonly employed.

2.1.1.1 Straight dipping

In straight dipping, a clean, dry former is immersed to the required depth in the latex mix, withdrawn slowly and dried. The operation may be repeated several times to build up the required thickness of rubber before the product is finally dried and vulcanised. The deposit thickness obtained in one dip by this process depends on the viscosity and total solids content of the mix, but may be about 0.05 mm. The straight dipping process is normally used only for the production of thin- walled articles, *e.g.* condoms.

Process Flow Chart



2.1.1.2 Coagulant dipping

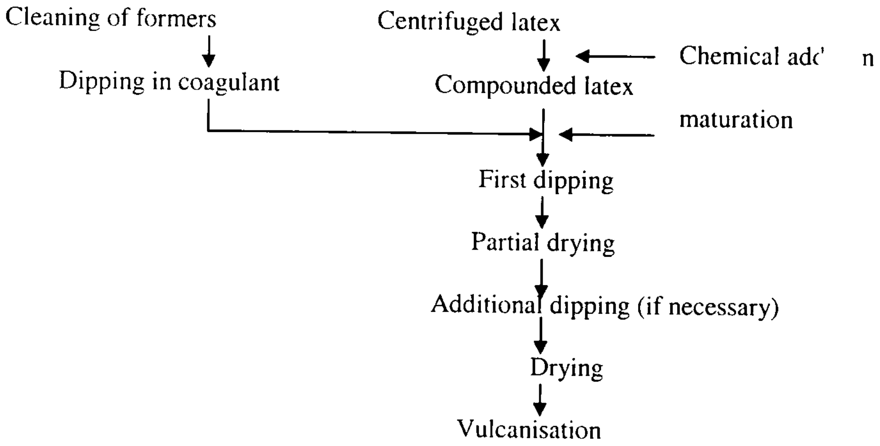
Coagulant dipping is the most widely used technique in the dipping industry. In this process a clean dry former is immersed in a coagulant solution, withdrawn, dried and then immersed in the latex mix. The function of the coagulant is to produce a greater deposit thickness than is achieved by "straight" dipping. The coagulant dipping process can be divided into two processes depending on the nature of the coagulant, i.e. dry coagulant dipping and wet coagulant dipping.

In dry coagulant dipping, the former is first immersed in a solution of the coagulant in a volatile solvent. Various coagulants may be used, but solutions of calcium nitrate in a mixture of water and methylated spirits are frequently employed. After withdrawal from the solution, the solvent is allowed to evaporate leaving either a dry deposit or one which is in the form of a very viscous, concentrated solution. The former, with its coagulant deposit, is then immersed in the latex and is allowed to dwell for a predetermined time and withdrawn from the latex. A thickness of up to 0.5 mm per dip is possible and the process may be repeated to build up a greater thickness.

In wet coagulant dipping, a fluid coagulant such as dilute acetic acid is used. The clean dry former is first dipped into the coagulant and then the excess is allowed to drain off. It is then dipped in the latex compound to dwell for a predetermined time. The disadvantages of this technique are the non- uniformity of the deposit and the tendency of the deposit to slip off of the former during the withdrawal unless the shape of the former prevents this. This slippage is due to the presence of a liquid layer between the deposit and the former.

withdrawal unless the shape of the former prevents this. This slippage is due to the presence of a liquid layer between the deposit and the former.

Process Flow Chart



2.1.1.3 Heat sensitive dipping

In heat sensitive dipping the latex is compounded with an agent which causes the latex to gel at elevated temperature. The formers are heated to 50-80^{0}C and dipped as for straight dipping. A single heat sensitive dip can produce a deposit of upto 4 mm and for this reason the process may be preferred to coagulant dipping for the production of thick-walled articles, such as teats, soothers and electricians' gloves. The thicknesses of the deposits produced by this process depends on the following factors:

a. degree of heat sensitivity of the latex compound
b. temperature of the former
c. heat capacity of the former

Polyvinyl methyl ether (PVME) is the most widely used heat sensitizing agent. A combination of ammonium salts and zinc oxide is also used, but they give mixes with inferior storage stability. The activity of PVME is very sensitive to pH and the pH of the mix should be kept between 9.0 and 9.5.

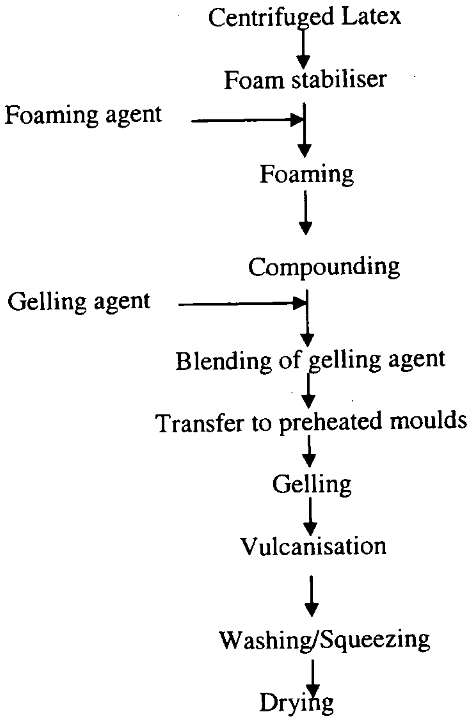
2.2 Latex foam

Moulded latex foam based on NR latex or a blend of NR and Styrene Butadiene Rubber (SBR) latices is used to produce a wide range of cellular rubbers used in the furniture, bedding and automotive industries. The original process, first patented by Dunlop in 1929, involved the use of sodium silicofluoride (SSF) as a delayed action gelling agent. The alternative system to this was developed in 1955 by Talalay and both systems are in commercial operation today.

In general natural rubber latex foam is produced by the aeration of a latex mix (Plate 9.1a) followed by the addition of a gelling agent which sets the rubber phase without destroying the foam structure. In the dunlop process, latex foam is produced by mechanical beating of the latex and then foam is blended with the vulcanising system. At the final stage, the gelling agent is added and the foam is poured into warm moulds. When SSF is added to the latex, gelation occurs within a few minutes at room temperature. Gelation is brought about by a reduction in pH as the SSF slowly hydrolyses. The mould containing gelled foam is heated in air or steam to effect vulcanisation. The mould is cooled and opened to enable the foam rubber to be removed (Plate 9.1b), washed, squeezed and dried.

In the talalay process for making latex foam, gaseous CO_2 is used to cause gelation of latex. In this process, the frothed latex is frozen at around -30^0C and CO_2 gas is passed through the foam, which causes a reduction in the pH with subsequent gelation of the foam. The foam is then heated to effect vulcanisation and subsequently stripped from the mould for drying.

Process Flow Chart



2.3 Latex thread

Latex thread is produced by the continuous extrusion of a suitably compounded latex through precision-bore glass or steel capillary tubes into an acid coagulant bath, often 25% acetic acid. This is illustrated in the following figure.

As in this figure the perimeter of the latex filament gels immediately on contact with the acid. As the filament passes through the bath the acid diffuses into the centre of the thread and total gelation occurs. The thread is then washed, dried and vulcanised.

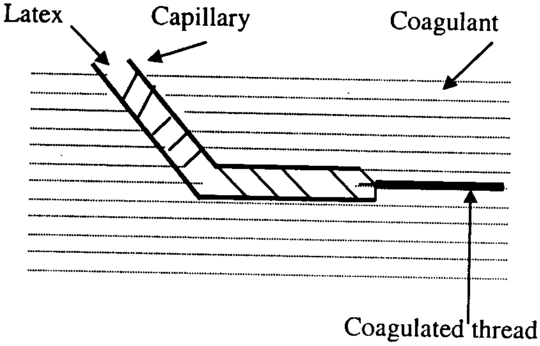


Fig. 9.1 Production of latex thread

2.4 Latex castings

The term casting refers to the process of forming hollow rubber products by depositing a layer of latex on the interior of a hollow mould. This may be done in plaster of Paris moulds where the plaster causes deposition of rubber, or in hot metal moulds using heat–sensitive latex mixes. These processes are used for the production of a range of children's toys, for film and stage-set parts, for advertising models, Halloween masks and for meteorological balloons.

2.4.1 Preparation of hollow moulds

Natural rubber latex when suitably compounded is an ideal material for the production of flexible moulds. A coat of natural rubber will dry to reproduce any characteristic indentations or markings of the surface on which it has dried. If the dried film is vulcanised, prolonged flexing and extension produce little alteration in the impression.

Moulds made from natural rubber latex are durable and are suitable for producing casts in cold setting resins and plaster of Paris. They are easy to produce, even for those who have no previous experience of using latex.

The procedure used in preparing the plaster of Paris moulds can be briefly described as follows:

The original article which is to be re-produced is called the "master". Generally a thin coat of pure gum latex should be applied to the master to ensure that the details are accurately reproduced. This initial coat can be applied either by dipping or brushing, but when the master has a lot of fine details brush application is done. Further coats of latex can also be applied either by dipping or brushing. Latex mould so prepared can be removed from the "master" after vulcanization. This latex mould is then used to prepare the plaster of Paris mould which will have the same impression as the "master".

2.4.2 Casting in plaster of paris moulds

This technique is very simple, can utilize a veriety of latex compounds and thus permits the formation of products having a wide range of hardness and flexibility. It depends on the deposition of a layer of gelled latex on the mould surface due to absorption of water by the plaster and to destabilization of the mix by calcium ions from the plaster. The procedure consists of filling the mould with the latex mix, allowing the filled mould to stand for a predetermined period to obtain the required deposition, pouring out the excess latex from the mould, and then drying and vulcanizing the product in the mould.

Moulds for this process should be made from fairly fine plaster of Paris powder, using a ratio of approximately one part powder to two parts of water. They should be made in two or more parts to facilitate removal of the product and must necessarily have a filling hole- usually sited in the base of the product.

2.4.3 Heat sensitive casting

This process can be carried out using plaster moulds but it is much more efficient if metal, e.g. aluminium or stainless steel, moulds are used. The procedure can be similar to the 'slush-moulding' moulding technique described above for plaster of Paris but moulds are heated to 70-80^{0}C before filling, or it can be of the rotational casting type in which the closed mould, containing a carefully measured quantity of latex mix, is simultaneously rotated about two axes and heated to the required gelling temperature. The latter process is used in meteorological balloon production.

3. DRY RUBBER-BASED PRODUCTS

The production sequence in the dry rubber products manufacturing industry can be fairly sharply and clearly defined into three stages.

1. Mixing
2. Shaping
3. Vulcanisation

3.1 Mixing

The rubber, processing aids, fillers, vulcanising ingredients and other additives, which the compounder has decided on, have to be mixed together. The two basic machines used for this process are the two-roll mill (Plate 9.2a) and the internal mixer (Plate 9.2b).

Prior to mixing NR, there is a mastication step. The reduction of viscosity and increase of plasticity of rubber is brought about by mechanical workin and by the application of heat. It is usually carried out on two-roll mills or in i nal mixers. .

3.2 Shaping

The second stage in the production is the shaping of the material into the shape required. There are three basic shaping techniques are used in the rubber industry as follows;

a. Compression moulding
b. Extrusion
c. Calendering

In addition to these, a rarely used technique known as the spreading method is also used as a shaping system of rubber mix on textiles.

3.2.1 Compression moulding

If the shaping is carried out by moulding, the vulcanisation stage is also achieved at the same stage. Moulding is a process in which the unvulcanised rubber is forced into a mould cavity of the same shape as that of the desired product, and is then vulcanised *in situ* in the mould cavity. The moulding processes for rubbers can be classified under three broad headings:

i. compression moulding
ii. transfer moulding
iii. injection moulding

In the compression moulding process, a suitable blank is placed in the open heated mould cavity, which is then closed and kept closed for a time which is sufficient to ensure adequate vulcanisation at the particular moulding temperature (Plate 9.3a). In transfer moulding, the rubber is preheated in a chamber prior to being forced through a channel into the mould cavity. Injection moulding is a kind of continuous transfer moulding, in which the unvulcanised rubber compound is injected into the mould cavity according to a predetermined cycle which comprises injection, vulcanisation, mould opening, ejection of moulding and closing of mould. Products like shoe soles, various bushes, rubber seals, various automotive components, rubber mats, etc. are made using either one of these techniques depending on the shape of the product.

3.2.2 Extrusion

The second type of shaping process which is used in rubber processing technology is extrusion (Plate 9.3b). In this process, the unvulcanised rubber compound is forced through a die, the shape of which is the principal determinant of the cross-section of the extrudate. Extrusion is used for the manufacture of products such as rubber tubing, insulated cables and weather sealing strip. It is also used for the production of tubes and other types of extrudate such as tyre treads which will be used subsequently for the construction of other products. But in all cases this shaping process is essentially distinct from the subsequent vulcanisation. Products like rubber hoses and rubber tubings are made using the extrusion technique.

3.2.3 Calendering

The third type of shaping process which is used in rubber processing technology is calendering (Plate 9.3c). Sheets of precision thickness can be obtained by this technique. In this process, the unvulcanised rubber is formed into a thin sheet by passing through heated steel rollers. The sheet may be either vulcanised as such, or be used for the building of other articles such as some components used in tyres. However, as in the case of extrusion, the shaping process is essentially distinct from the subsequent vulcanisation.

3.2.4 Spreading

This again is a process for applying a thin layer of rubber to textile fabric. In this case, the rubber is applied in admixture with a rubber solvent, the mixture being commonly known as dough. Spreading is achieved by passing the fabric between a roller and a doctor blade.

3.3 Vulcanisation

The final step in the manufacturing sequence is vulcanisation of the shaped product. Basically, the vulcanisation is carried out by heating at an elevated temperature for a predetermined period of time. As stated earlier in most cases vulcanisation is combined with the method of moulding.

A flow diagram illustrating the basic principles of dry rubber-based products manufacture is given in Fig. 9.2.

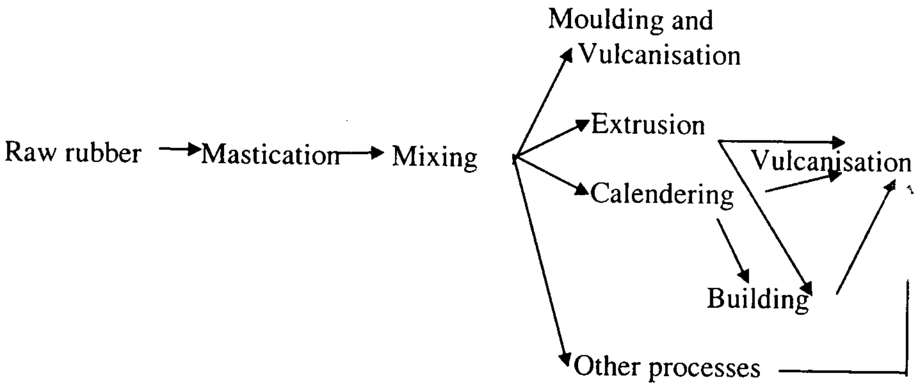


Fig. 9.2. Flow diagram illustrating basic principles of dry rubber-based products manufacturing technology

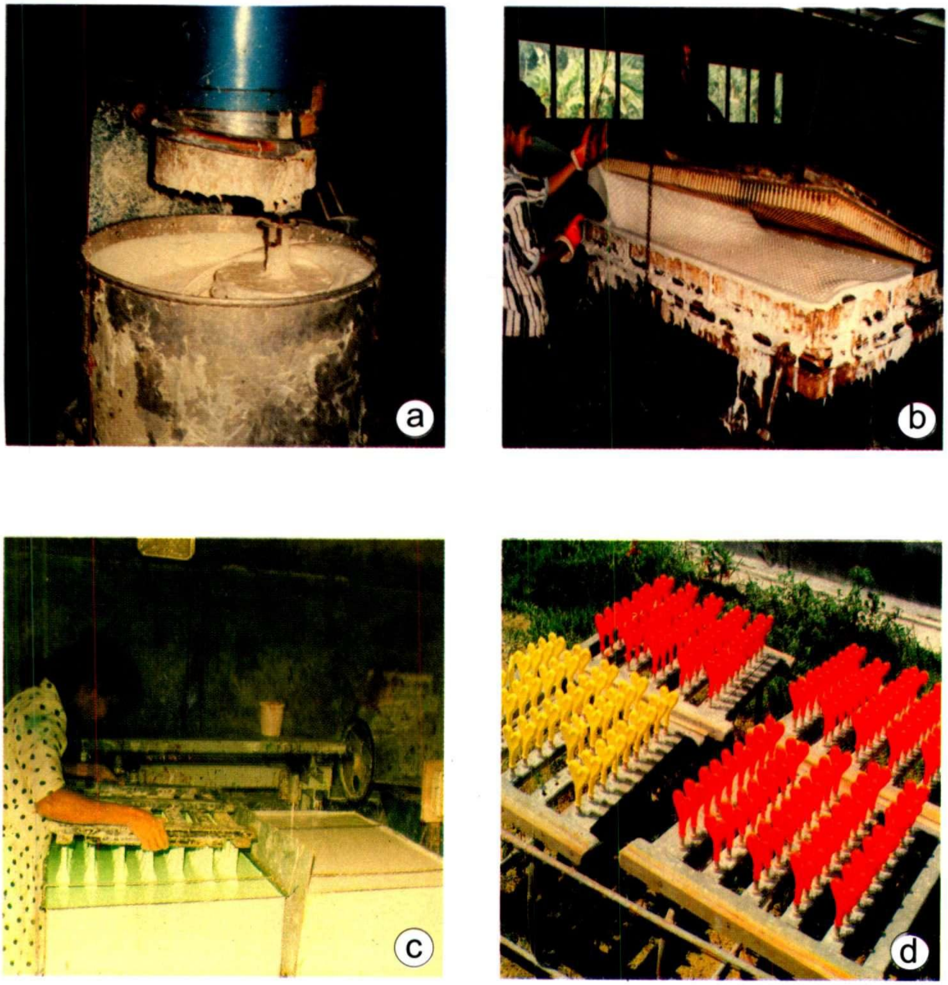


Plate 9.1. Manufacture of foam rubber and balloons. **a** Batch foaming by whipping process; **b** Removal of moulded foam article from the mould after vulcanization; **c** Hand dipping in balloon manufacture; **d** Drying and vulcanization of balloons under the hot sun.

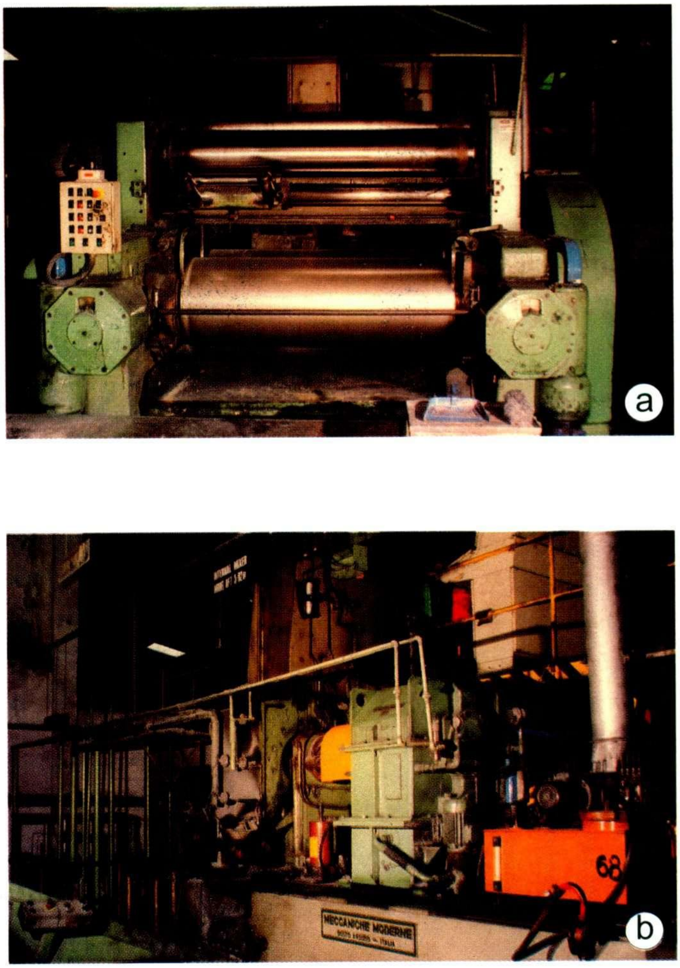


Plate 9.2. Machinery used for rubber compounding. **a** A modern two roll mill with stock blender which is shown above the bigger two rollers; **b** Banbury mixer.

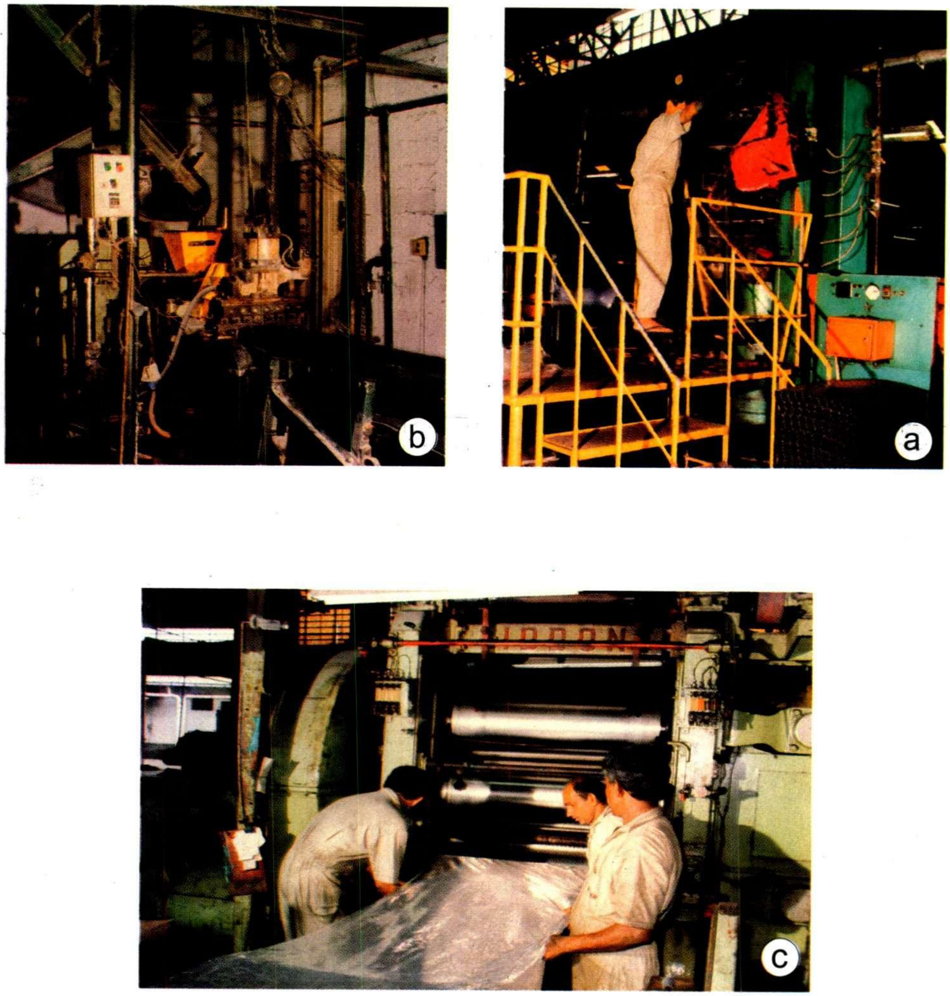


Plate 9.3. Equipment used for shaping of rubber products. **a** Hydraulic press for compression moulding; **b** Extruder; **c** Calender.

Chapter 10

Water used in raw rubber manufacture[*]

U.N. Ratnayaka

1. INTRODUCTION

A plentiful supply of water is required for the manufacture of rubber. It is estimated that about 30 – 50 litres are necessary per kg of crepe and 50 – 60 litres per kg of block rubber from latex and field coagula. This water is required for dilution of the latex, for washing away the serum substances during machining, preparation of solutions of chemicals, cooling the mills, cleaning the factory *etc.*

The quality requirements of the water used at various stages of manufacture are different. It is necessary that the quality parameters of water meet the standards in order to avoid difficulties in manufacture and to prevent deterioration in quality of the rubber. The water should be without colour and smell and should not contain too high a concentration of iron, manganese and calcium.

Quality requirements

The following specifications for water have been suggested based on several years' practical experience, as a guide for good quality rubber manufacture:

Iron	1 mg/litre
Copper	0.5 mg/litre
Manganese	0.5 mg/litre
Permanganate value	20 mg/ litre
Lime content	30 mg/litre
Bicarbonate	300 mg/litre
Hardness	60 mg/litre
Floating dirt	10 mg/litre (smaller than 325 mesh)
pH	5.8 – 8

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[*] Adapted from "A Handbook of Rubber Culture and Processing", 1983

The above specifications are not to be considered as fixed upper limits but rather as a general guide.

The choice of water is generally restricted and the composition, dependent on the place of origin and the season, may vary to a great extent, so that the above requirements cannot often be fulfilled even after chemical treatment. Hence under such conditions some concessions have to be allowed.

2. SOURCE OF WATER SUPPLY

The different types of water which may be available on estates, classified according to their respective sources, are as follows;

2.1 Artesian water

Water from aqueous layers, sometimes up to 275 m deep, is obtained by boring shafts which go through impermeable layers to the water layer. This type of water is clean, free from micro-organisms and has usually few or no impurities other than sand. Depending on the geological structure of the under-ground strata, artesian water may, however, contain a high concentration of iron, manganese, bicarbonate, sulphur or calcium or it may be too hot for immediate use.

2.2 Well water

Water from subterranean layers which penetrates to the surface at certain points, if not contaminated by contact with soil water and surface water, has usually the same properties as artesian water.

2.3 Soil water

Water which collects on water–impermeable layers and forms a stagnant water horizon. Such water is mostly contaminated with organic and inorganic matter.

2.4 Running surface water

Water from rivers and streams contains floating dirt. However, it must be pointed out that a river with muddy water in rainy weather, may in the dry season have very clear water, which may be used without any treatment.

2.5 Standing surface water

Water from lakes and swamps is normally contaminated with floating dirt and has sometimes a high content of various salts.

3. PURIFICATION OF WATER

Slightly coloured or opalescent water can be used for rinsing and cleaning but it should be free from suspended matter.

The water used for standardisation of latex should be as pure as possible. This can be obtained by using a metal-sand filter.

A simple average size road metal-sand filter could be prepared as follows:

Water is filtered through a filtering medium consisting of different size road metal and sand. Sand is packed at the top followed by road metal in ascending order of size towards the bottom (Fig. 10.1).

Cleaning of the filter system is only necessary if the rate of outlet falls low below the required level. This can be done by using a back washing system.

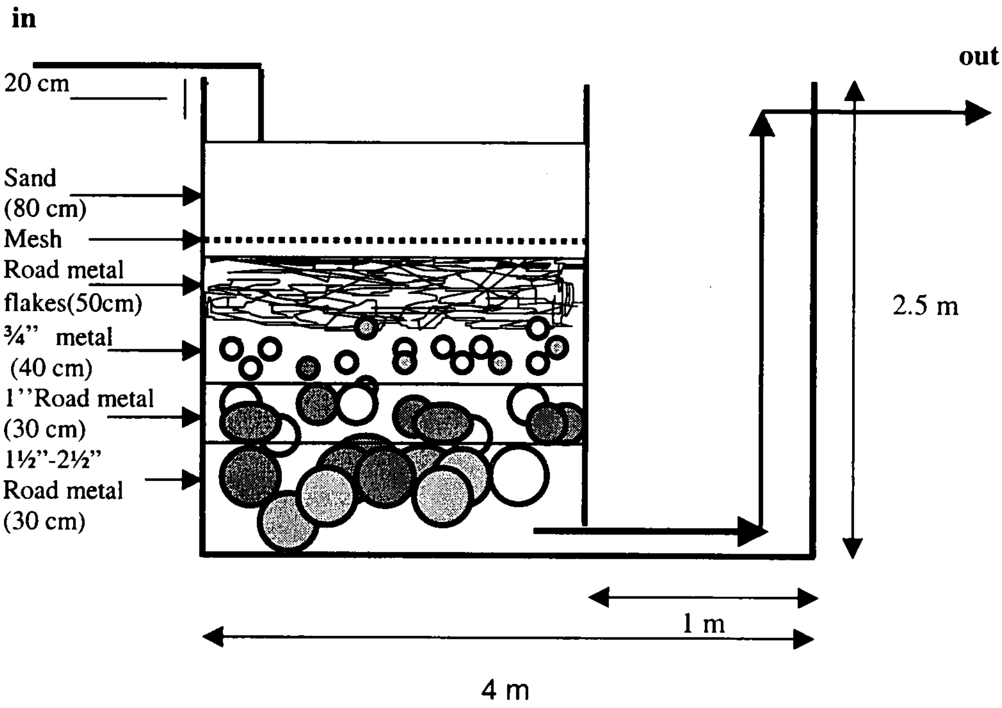

Fig. 10.1. Simple road metal – sand filter system

4. EFFECT OF METALS AND SALTS ON QUALITY OF RAW RUBBER

Iron content

It may often be observed that apparently clear water which is allowed to settle for several hours in a container shows a reddish brown colouration. This is caused by iron which in most cases is dissolved in the water as ferrous bicarbonate and this is precipitated as ferric hydroxide in the form of a brown mucilaginous mass by contact with air as per the following chemical reaction.

$$4Fe(HCO_3)_2 + 5O_2 + 2H_2O \longrightarrow 4Fe(OH)_3 + 8CO_3^{2-}$$

or if the dissolved iron is in the form of sulphate the following reaction takes place.

$$4FeSO_4 + O_2 + 10H_2O \longrightarrow 4Fe(OH)_3 + 4H_2SO_4$$

Artificial aeration by spraying nozzles or by splashing over weirs, cascades or granulated materials increases the speed of this precipitation.

If high iron-containing water is mixed with latex, precipitation takes place and red-brown spots resembling mould are often observed in crepe rubber. In contrast to rust particles from the water pipes, these spots do not have the same characteristic shape. A high iron content in the water is sometimes linked with a high manganese content. Very small amounts of manganese affect the durability of rubber. It is necessary that the water should be treated to remove this impurity. As manganese shows a similar reaction to iron, both metal ions may, in most cases, be precipitated by aeration and the precipitate removed by filtration.

Although the maximum iron content allowed for water is 1 mg/l for crepe rubber manufacture, 3 mg/l is allowed for smoked sheets. It is not possible to manufacture a reasonable white or spotless crepe if the iron content of the water is higher than approximately 1 mg/litre. The effect of discolouration may be increased if a high iron content is linked with too high a permanganate value. The problem is less severe with sheet manufacture as the discolourations are masked by the colour of the sheets.

Copper and manganese content

Because of the harmful effect of even very small amounts of copper and manganese on the service life of rubber, the limits given in the specification for water have been arrived at as the maximum allowed. In drafting such standards for water used in manufacture, a considerable margin has been thus included in formulating limits.

Permanganate value

The permanganate value of water, expressed as mg potassium permanganate per litre, is generally taken as an indication of oxidizable organic matter. Water with a high content of organic matter is always heavily contaminated by micro–organisms, while this organic matter itself creates a favourable environment for further development of fungal and bacterial growth, resulting in pronounced discolouration of crepe rubber and the appearance of spots with a full range of colours.

Dirt content

The use of water with large dirt particles may cause a decrease of good quality output or may even affect the colour of the crepe. Therefore, dirt including coarse organic matter of a particle size larger than 325 mesh, which is taken as the standard for determination of contamination in rubber, should be avoided. The standard has been fixed at 10 mg/litre of dirt, provided it is smaller than 325 mesh.

As far as coarse impurities are concerned, they may easily be removed by filtration or decantation. Water containing colloidal impurities is not easy to purify by filtration. Therefore it must be first treated with a saturated solution of alum and thereafter the supernatant water can be used. Besides large particles, a large amount of dissolved iron and manganese will be removed by this alum treatment. The amount of alum required is dependent upon the impurities in water and varies approximately between 4 and 10 g per 100 litres of water. A large part of the dissolved alum will also be removed along with the precipitated colloidal impurities so that the remaining part will cause no harm, when using this purified water for dilution of the latex.

Carbonate and bicarbonate content

The most common salts in water are of calcium and magnesium in the form of carbonates and bicarbonates, the presence of which causes the total hardness or soap-consuming power. "Temporary hardness" refers to that part which is destroyed by boiling the water and is due to the presence of bicarbonates.

A high content of calcium and magnesium salts may cause precoagulation. Generally, difficulties may be experienced when the concentration exceeds 50 mg $CaCO_3$ per litre. Normally river water has the lowest percentage of calcium and magnesium.

A high content of bicarbonates may be the reason for the occurrence of gas bubbles in sheet because of the liberation of carbon dioxide. 300 mg/litre seems to be the maximum limit; however, a higher content can be tolerated in the manufacture of crepe.

If necessary the bicarbonate can be converted into practically insoluble carbonates by adding lime water to the water concerned or by treatment with sulphuric acid; finally it can be concluded that the water used in the manufacture of rubber should be quite pure in order to avoid difficulties in manufacture.

Chapter 11

Defects in raw rubber*

W.M.G. Seneviratne

1. INTRODUCTION

The main and most common reasons for the occurrence of various defects in raw rubber are lack of adequately controlled conditions, failure to adopt correct practices, carelessness, as well as lack of cleanliness.

2. DEFECTS IN RIBBED SMOKED SHEETS

The principal defects, *e.g.* bubbles, mould and rust, result mainly from the action of micro-organisms and therefore utmost care should be taken to reduce any chances of microbial contamination of latex and coagulum to a minimum, by maintaining the maximum cleanliness during all stages of manufacture. All

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* Adapted from "A Handbook of Rubber Culture and Processing", 1983

containers, receiving tanks, bulking tanks and coagulating tanks, as well as the floor of the factory should be disinfected at regular intervals, preferably once in every 2 weeks, with a suitable disinfectant, in order to prevent the build-up of micro-organisms, mainly at the edges of tanks, in the lining between tiles and in all the crevices in concrete and damaged tiles *etc*.

Thickened or precoagulated latex contains bubbles and the use of anticoagulants is advised for prevention of precoagulation. For smok d sheets, ammonia or sodium sulphite is the preferred anticoagulant. Soda ash when applied in excess may cause bubbles.

One of the faults often observed during manufacture is the use of insufficient acid for coagulation, resulting in a serum containing up to about 1.5% of rubber which makes it milky or cloudy. Due to insufficient acid, coagulation proceeds very slowly and fermentation may occur, resulting in the formation of bubbles.

In general, under properly controlled conditions, the use of sodium bisulphite to prevent enzymatic discolouration of rubber is not required for the manufacture of smoked sheet rubber and hence the use of sodium bisulphite is not generally recommended. Only in cases where signs of enzymatic oxidation occur due to inherent properties of latex or unavoidable deviations from the standard manufacturing process, the use of sodium bisulphite at a dosage of not more than 50 g per 100 kg of dry rubber may be permitted. Excess sodium bisulphite will cause tackiness in the finished sheets and will, moreover, prolong the drying time. The presence of small bubbles may also be due to the use of excess sodium bisulphite, which decomposes with the addition of acid.

The main defects in sheet rubber are detailed below;

2.1 Bubbles

The cause of bubble formation is not always easy to trace and may be found both in the field and in the factory. Bubbles are usually due to fermentation of latex or the coagulum, (air being trapped in the coagulum) the use of an excess of acid, or of acid of too high a concentration, or decomposition of soda ash and sodium bisulphite.

Generally the following types of bubble may be distinguished:

i. Clusters of pinhead bubbles centred on small specks in the rubber or streaks with and without bubbles randomly distributed over the sheets; these are mainly caused by premature clotting of latex before coagulation due to either the non-addition of anti-coagulants, by contamination with rain water, use of dirty utensils, tanks or pans, or by the use of acid of too high a concentration. In the small clots, gas is developed from serum components by the action of micro-organisms. These groups of bubbles may often be accompanied by flecks without subsequent fermentation.

ii. Small pin head bubbles frequently appearing at the edges or corners of the sheets may be due to insufficient dilution of latex, insufficient mixing of latex with acid, or to the use of an excess of acid.

iii. Air and gas bubbles of irregular size scattered all over the sheets or appearing only on one edge of the sheets: these may be caused by air trapped in latex which could not escape due to insufficient dilution or fast coagulation or by insufficient skimming of the surface after mixing with acid. Depending on the type of coagulation, *i.e.* tank or pan, the bubbles appear only on one edge or dotted over the sheet. Fermentation of latex before and during collection, fermentation of the slabs or the wet sheets due to a prolonged time between coagulation and milling or to a prolonged dripping time are other possible causes. These bubbles may also originate in the smoke house due to unfavourable smoking conditions.

iv. Large bubbles and blisters, which originate always in the smoke house, due to too high a smoking temperature, mainly in the first stage of drying: their occurrence will be more pronounced if the thickness of the sheet is above normal.

The main causes for the formation of bubbles are:

a. Incipient precoagulation in the field due to instability of the latex and non-addition of anticoagulants, late arrival of latex at the factory, or an excessive time interval between arrival and coagulation.

b. Contamination of latex with rain water or tapping of wet trees: in both cases anticoagulants should be used in the field. On days when contamination with rain could be expected, the amount of anticoagulant normally used may be increased by 50 to 100%.

c. Exposure of latex to the sun.

d. Use of dirty spouts, cups or collecting buckets.

e. Dilution of latex with unsuitable water. Water with too high a content of lime, bicarbonate or dirt, or too high a permanganate value, or water which shows an acidic reaction, may cause thickening of the latex during dilution.

f. Presence of air bubbles in the latex. The causes for this defect are insufficient dilution of latex, fast coagulation due to excess of acid, or to the use of acid of a higher concentration than recommended.

g. Addition of certain adulterants to latex, such as starch, clay, plant juices, *etc.*

h. Insufficient acid, as denoted by milky serum.

i. Insufficient straining or skimming of latex.

j. Fermentation taking place in the wet sheets while dripping for a prolonged period. Prolonged dripping should be avoided.

k. Too much soda ash anticoagulant or too much sodium bisulphite, which decompose after addition of the acid with evolution of gases (carbon dioxide and sulphur dioxide, respectively).

l. Prolonged drying due to too low a temperature and inadequate ventilation. Air bubbles appear mainly in the ribs on thick edges of the sheet and on the surface areas where the sheets are in contact with the "reepers". Therefore, it is important to ensure that the smoke house maintains the correct smoking temperature as soon as possible after insertion of the wet sheets, that it is not operating at a low temperature, especially during the night, and that it is adequately ventilated. Large amounts of water have to be evaporated off during the first few hours of drying.

m. Too high a smoking temperature, especially during the first stage of smoking, may cause large bubbles and blisters. For RRS type of smoke houses, where crops of different days are accommodated in the same chamber, the temperature should be in the range of 48 -54 ^{0}C and should not exceed 60 ^{0}C.

2.2 Rust

Rust is a brownish deposit or a thin film on the surface of the dry sheets which becomes visible as powdery or scaly substances when the sheets are stretched or scratched with a blunt object. It is caused by fermentation of the non-rubber constituents on the surface of the wet sheet due to development of bacteria, yeast or certain fungi during the period between rolling and drying. The occurrence of rust can be traced to the following causes:

a) Inadequate washing of the sheets during and after milling.

b) Prolonged dripping of wet sheets.

c) Too low a temperature and bad ventilation in the smoke house, especially during the early stages of drying.

d) Use of badly worn out hand-operated mills, whereby most of the serum substances which should be squeezed out remain in the sheets.

For the prevention of rust:

i. The sheets must be well washed during milling and should be soaked for a short time after milling in running water. Hand-operated mills should be fitted with water sprays at their nips. There should always be plenty of water at the mills.

ii. The dripping time of the sheets should not exceed 2 to 3 hours. Wet sheets should be allowed to drip by hanging them on "reepers", preferably in a draught.

iii. The wet sheets should be inserted immediately after dripping into a warm smoke house and a smoking temperature of 50 ^{0}C must be obtained shortly after insertion.

iv. During the first few hours of drying there must be sufficient ventilation in the smoke house to remove the bulk of the moisture evaporating from the surface of sheets.

2.3 Mould

Smoked sheets, despite the preservation afforded by creosotic and antiseptic substances from the smoke, are liable to develop mould if allowed to become damp. The non rubber constituents create an environment favourable to the development of mould when the moisture content of the sheets becomes higher than about 0.8%. The sheets should come out of the smoke house with a water content of less than 0.5%, but as the equilibrium moisture content under conditions of high humidity may be above this limit, the sheets pick up moisture rapidly, activating the spores of mould. Mould grows on the surface of the sheets forming dusty layers, but may also penetrate inside the sheets. Storing of dry sheets under humid conditions on cemented floors, in badly ventilated rooms which promote the absorption of moisture, as well as unfavorable smoking conditions and heavy infection of the smoke house, are the main causes for development of mould.

The following precautions should be taken to reduce the incidence of mould growth:

i. The freshly milled sheets should be soaked for a short time in running water.

ii. Attention should be paid to proper smoking conditions, a constant temperature of 50-60^{0}C and sufficient ventilation.

iii. The smoked sheets should be sorted and made ready for transport as soon as possible after their removal from the smoke house. Sorting and storage should be done in a dry, well ventilated room or section.

iv. Sheets should never be stored on a cemented floor or on coir matting, gunny bags or similar material, but only on planks, or on a wooden platform allowing some air circulation from underneath. If sheets are found to be mouldy, they may be brushed with a soap solution or a 0.5% formalin solution, and re-smoked and dried for 12 to 24 hours.

In smoke houses where drying is delayed due to low temperature or to a prolonged handling time, outbreaks of mould may often occur during the wet season and could be a constant source of contamination. For the elimination of mould in smoke houses, spraying with a 1% solution of formalin on all parts inside the smoke houses, including floor, walls and roof, may be recommended. A very effective method is to evaporate 2-4 litres of concentrated formalin (about 38%) in the smoke house which is then kept closed for about 24 hours. The formalin is heated in a suitable container on a small charcoal fire. The gaseous formaldehyde penetrates into all cervices and destroys germs effectively.

2.4 Tackiness

Tackiness of sheets of different grades from very slight to heavy may be caused by:

a. The use of an excess of sodium bisulphite.
b. Too high smoking temperatures.
c. Too slow drying during the first stage.
d. Contamination with copper salts from fungicides or with copper present in some lower grade coagulants.
e. Contact with oil from the bearings of the rollers.

It should be mentioned that latex from young trees might sometimes produce sheets showing a slight tackiness.

2.5 Greasiness

Sometimes sheets taken out of the smoke house are greasy and rapidly become moist. This is mainly due to the exudation on the surface of the sheets of serum substances which are hygroscopic and capable of absorbing water from the air. A greasy surface usually results from to insufficient washing during and after rolling or to insufficient dilution of the latex. This defect could be overcome by soaking of freshly milled sheets in running water for a short period of time in order to remove serum substances.

2.6 Glossy surface

This is due to the use of wet firewood or a fuel such as coconut shells and husks which produce too much creosote. Creosotic compounds deposit on the surface of the sheet resulting in glossiness. Therefore, only dry firewood (*Hevea* or jungle wood) should be used for smoking of rubber.

2.7 "Specky" sheets

The presence of dirt particles in the rubber is usually due to bad straining of latex or the use of dirty dilution water. Sometimes masses of minute bubbles are mistaken for specks of dirt. Rubbing the sieves too vigorously during straining of the latex should be avoided, because dirt particles are pressed through the wire mesh. Pans or coagulation tanks should be covered after coagulation. Dilution water should always be strained through a fine cloth, which may be fixed directly to the tap as a small bag. In case of high contamination, settling or filtering through a simple sand- metal filter should be carried out.

It may often be observed that apparently clear water when allowed to settle for several hours in a container, shows a reddish brown precipitation due to oxidation of the high content of dissolved iron. Iron compounds in water may be oxidized by different "iron bacteria" which are very common and which grow frequently in water pipes, containers *etc.* They may develop so prolifically that large mucous clusters may be formed in the containers or may come out of the pipes.

2.8 Ash particles on sheet

The baffle plate over the furnace may be too small, the protective gauze may not be fine enough, the fire may burn too fiercely or there may be too much wind or draft in the stoking place to cause this defect. If the firewood is carelessly thrown on the fire, a lot of fine ash particles may be blown into the smoke house. Smoke houses with an outside furnace can be protected by building a simple ash barrier in the flue.

2.9 Tar spots

They are caused by tarry drops of water falling onto the sheets in the smoke houses. This happens mainly in the rainy seasons, if the roof is covered with GI or corrugated iron sheets. The roof becomes cold in the night and hence water condenses. Better ventilation would prevent this effect to an appreciable extent. Smoke house should preferably have a V-shaped ceiling with an adjustable ventilator opening. Alternatively a hessian cloth hung under the roof could also be used.

Care should be taken to see that no sheets are hung under the ventilation opening or, alternatively, a bowl should be fitted under it, in order to collect condensed water drops contaminated with tar.

2.10 Thick edges

These may be due to insufficient dilution of latex or insufficient use of acid in tank coagulation, irregular shaped pans, pans or tanks of latex placed on a surface which is not level, unskillful handling of coagulum, coagulum becoming doubled up during rolling or to displacement of partitions in the tanks. It can also be due to uneven wearing of the rollers at their ends.

2.11 Discolouration of coagulum

Primarily grey, pink or yellow discolouration on the surface of the coagulum is caused by enzymatic oxidation of the polyphenolic compounds. To avoid this discolouration, the surface of the coagulum should be covered as early as possible after formation, with a layer of about 1 to 2 inches of water containing a little amount of sodium bisulphite.

Discoloured patches on the wet sheets are mainly due to a prolonged dripping time. Slight patches generally disappear during the smoking process. However, if these patches do not disappear, 50 g of sodium bisulphite per 100 kg of rubber may be added, but this amount should not be exceeded as the chemical retards the drying of sheets to a considerable degree.

2.12 Flat roller prints

A too hard coagulum, owing to insufficient dilution of latex or use of excess acid, coagulum rolled too thin in smooth rollers or in wornout marking rollers with shallow grooves, may cause flat or indefinite marking of the sheets.

2.13 "Reeper" marks

A light mark across the centre of the sheet is caused when the sheet has not been moved daily during smoking. If "reepers" of round section are used, the sheets can be moved easily by rotating the "reepers". A dark mark is usually due to the use of dirty "reepers".

Common defects in RSS and their remedial measures are given in Table 11.1

3. MAIN DEFECTS OBSERVED IN LATEX CREPE (THICK, THIN AND SOLE CREPE)

Even though latex crepe is made to pure white colour by taking all precautions to prevent discolouration caused by plant pigments, enzymes, metal ions and mould growth, the following types of discolouration could frequently be observed in crepe rubber:

a. Enzymatic discolouration apparent only after drying.
b. Yellow discolouration caused by carotenoid pigments
c. Storage discolouration caused by polyvalent metal ions reacting with amines and diamines present in latex. (Visible only a few weeks after manufacture).
d. Mould contamination appears as pink, green or brown spots first which then turn black or dark brown.

3.1 Enzymatic discolouration

Caused by the polyphenolic compounds present in latex which undergo oxidation, catalysed by enzymes. These oxidised products are dark in colour and hence the laces turn pink, yellowish, grayish or black. This can be controlled by adding an enzyme inhibitor like sodium bisulphite or metabisulphite just after bulking of latex.

Recommended dosage

500 g of the lump-free chemical per 100 kg of dry rubber as a freshly prepared 1% solution.

Table 11.1 RSS manufacture - faults and corrective measures

Fault/Defect	Possible cause	Corrective measure
1. Drying time is too long or undried spots	Temperature too low. Sheets too thick	Keep temp. around 50 ^{0}C. Mill the sheets to standard thickness (2.5 mm)
2. Pinhead bubbles	Precoagulation in the field. Use of dirty equipment, fermentation effects and bacterial growth	Use a preservative in the field, use an antiseptic to disinfect the utensils and correct dosage of acid for coagulation
3. Blisters	Overheating due to sheets being too close to the fire.	Keep sheets away from fire and set up proper temperature control in the smoke house. Place a baffle plate over fire
4. "Reeper" marks	Unclean "reepers", inadequate rolling of sheets during drying, use of unseasoned wood for "reepers"	Clean reepers periodically. Roll sheets daily. Season the wood before use
5. Light colour (not necessarily a defect)	Use of unconventional fuel source	Change to dry firewood (conventional types)
6. Dark colour	Enzymatic discolouration. Inadequate washing of sheets. Dripping time too short. Use of slaughter tapped latex	Add sodium metabisulphite prior to the addition of acid. Increase dripping time to at least 2 hours after adequate washing. Process the slaughter tapped latex separately
7. Rust	Inadequate washing of sheets during and after milling, excessive dripping time	Wash the sheets well during and after milling, reduce the dripping time, increase the temp. in the smoke house after insertion of wet sheets without delay
8. Glossy surface	Use of wet firewood or excessive proportions of coconut or paddy husks	Use dry firewood

Precautions to be taken

Solid salt (bisulphite or metabisulphite) must be stored in a dry place preferably in a tightly closed container. Hardened lumps which cannot be crushed with the fingers must not be used.

Storage of wet crepe mats until next day for smooth milling aggravates this situation. The factory personnel sometimes are compelled to postpone smooth milling of part of the crepe mats to the next day due to inadequate smooth milling capacity or due to breakdown of one or several smooth mills. As this is the bottleneck of the entire milling operation an adequate number of smooth mills should be made available and any breakdown should be immediately rectified. Under unavoidable circumstances, it is advisable to keep the mats immersed in a mild solution of sodium bisulphite till they are smooth milled the next day. Milled laces should be dispatched to the drying tower without keeping them stacked outside for too long, as delay in drying also causes this discolouration. This could also happen in the drying tower, if the laces are left in the wet condition for too long due to improper operation of the drying tower. Adequate ventilation should be ensured specially during the initial stage of drying of laces.

3.2 Yellow discolouration

This is caused by the carotenoid pigments present in small quantities in latex mainly in the lutoid phase. The lutoid particles being most unstable, most of the pigments can therefore be removed by fractionation. Only the remainder after fractionation is bleached by means of sodium para toluene thiophenate available under the trade names Nexobleech, RPA 4, Polybleach and Rupepa. Preparation of the stock solution and addition of the chemical to latex are explained in chapter 3.

The correct procedure for removal of the yellow fraction is also explained in chapter 3. Deviation from this procedure may lead to non-removal of the fraction containing the pigments. The actual percentage of the yellow fraction lies in the range of 6 to 8%. The fraction removed may not, sometimes, contain the pigments but may include a considerable amount of rubber particles in it. Most probably this is due to the improper standardization (inadequate dilution) of latex prior to fractionation. A very common reason for this is the inadequate bulking capacity and hence standardisation (dilution) of latex to the required DRC cannot be done. The ultimate result is that a part of good rubber which should have gone into the white fraction (No 1X grade) is lost in the yellow fraction and also a considerable amount of yellow pigments might remain in the white fraction causing yellow discolouration which cannot be rectified by addition of an increased dosage of bleaching agent. Furthermore, excess of bleaching agent may cause storage softening; but does not further improve the colour of laces.

The amount of active ingredient in bleaching agent is between 35 and 38%. This is a clear syrupy liquid with a few needle-type crystals floating on the surface. If many crystals are present, effective thiol content must be checked before use. Crystal formation in water-soluble bleaching agent reduces the active ingredient content in the solution and hence the use of the normal dosage would not be adequate to bleach the remaining colouring matter in latex after fractionation. Once the container is opened for removal of part of the chemical, it should be tightly closed immediately, to prevent crystal formation.

Also the bleaching agent must be added as a freshly prepared solution into latex. Any excess should not be poured back into the main can or kept in a container to be used the next day. The required dosage is 2-3 litres of 5% solution to bleach 100 kg of rubber.

3.3 Storage discolouration

This is a slow process and can be seen only few weeks after manufacture. This defect is caused by amines and diamines present in latex which combine with polyvalent metal ions usually present in hard or contaminated water. Storage discoloured rubber is usually dull, beige or brown in colour.

The precaution to be taken to prevent this defect is the use of soft (treated) clean water. This is the only way to avoid this problem. The use of oxalic acid, fully or together with formic acid is recommended only for sole crepe manufacture and that too in exceptional situations.

3.4 Mould contamination

This is the most common problem associated with lace crepe rubber and to some extent with sole crepe too. The only method to prevent mould growth is controlling the level of moisture in the rubber. Hence,

i. laces must be made as thin as possible to ensure drying within three days.
ii. ventilators and the efficiency of radiators in drying towers must be checked regularly.
iii. laces hung in the drying tower must not touch each other and there must be a space between laces.
iv. loft drying is not advisable for thin lace and sole crepe manufacture.
v. all dried laces must be stored under clean and perfectly dry conditions.

Under no circumstances should inadequately dried laces with tiny white spots be removed from the drying tower and packed with good laces to be dispatched to shippers.

Packing material must be perfectly dry and the use of albizia boxes for packing sole crepe is not permitted. Corrugated cardboard boxes should be used for this purpose.

4. OTHER POSSIBLE DEFECTS OF CREPE

4.1 Dull apearanace/Brown discolouration

Direct exposure to sunlight, the use of inadequately cooled mills and high drying temperature could impart a dull appearance to the laces. Brown discoloration is possible when impure water is used during manufacture and the effect is predominant especially when water is contaminated with a high level of iron.

4.2 Streaking or mottled crepes

Clot formation by rain drops falling into latex buckets (pre-coagulated latex) causes yellow steaks on laces. Blanketing of different coloured laces together also imparts mottled appearance and streaks. Surface mould, poor mixing of insufficiently diluted sodium bisulphite and insufficient skimming also cause streaks in crepe.

4.3 Tackiness

Tackiness of crepe laces can be caused by contamination of latex with copper and manganese ions. Exposure to heat, use of excess bleaching agent and milling of rubber on heated rollers are some possible reasons for tackiness in crepe rubber.

4.4 Splitting

This defect is found in sole crepe. The sole crepe should be properly laminated so that the laces would not separate under pressure. If the laces used are inadequately dried with moisture still in it or laminated on wet days splitting of sole crepe may occur. Further, if the pressure applied in the laminator is uneven the side with less pressure may tend to split. In order to overcome the problem of splitting in sole crepe the following measures should be taken;

- Use of only well dried laces for laminating
- Fixing of a 500-1000 watt electric bulb in close proximity to the laminating roller to heat up the surrounding air. It is preferable to avoid lamination of sole crepe on wet days.
- Adjustment of the pressure of the laminator rollers evenly.

4.5 Roller marks

Roller marks may appear at regular intervals on the finished product due to bottoming of end gears and slipping of belts. In order to overcome this effect due to end gear bottoming, the root diameter of the teeth should be reduced and machined. Also make sure the correct profile of the teeth end gears is maintained. Belts should be tight and firm to avoid the roller marks due to slipping of belts.

Chapter 12

Sorting, grading and packing of visually graded rubber

W.M.G. Seneviratne

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1. INTRODUCTION

RSS, pale crepe and brown crepe are traded on a visual assessment of quality. To establish acceptable grades for commercial purposes the "Green Book" classifications are used.

The following general prohibitions are applicable to all grades of RSS, pale crepe and brown crepe.

- Wet, bleached, undercured and virgin rubber and rubber that is not completely visually dry at the time of buyers' inspection is not acceptable (except slightly undercured rubber as specified for RSS No.5).
- Skim rubber made of skim latex shall not be used in whole or in part in the production of any grade described in this chapter.

Those grades, latex or scrap, that fail to conform to the specifications of any one of the individual grades listed under section 3, 4 and 5 fall into "in between" categories such as 1A or (1-), 2A or (2-) and so on. A considerable quantity of such off-quality crepe is produced and these are bought by shippers for their clients, who have uses for them. Invariably the shippers would have provided their clients with samples that would indicate the sort of defects within these off-quality crepe and each shipper would use his own nomenclature to describe these grades. As they do not conform to international standards, they are referred to as "House grades".

2. GRADING OF RIBBED SMOKED SHEETS (RSS)

Only deliberately coagulated rubber sheets, properly dried and smoked can be used in making these grades. Prior to grading sheets are separated, inspected and any blemishes are removed by cutting with a pair of scissors (Plate 12.1a).

2.1 No.1X RSS-Superior Quality Ribbed Smoked Sheets

The grade must be produced under conditions where all processes are carefully and uniformly controlled. The rubber must be dry, clean, strong, sound and evenly smoked, and free from blemishes, specks, rust, blisters, and any foreign substances. Small pinhead bubbles, if scattered, will not be objected to.

No type sample is available for this grade since it is no longer in volume production.

2.2 RSS No. 1- Standard Quality Ribbed Smoked Sheets

The rubber must be dry, clean, strong and free from blemishes, rust, blisters, sand, dirt and any other foreign matter except very slight, isolated specks. Small pin head bubbles, if scattered will not be objected to.

Oxidised spots or streaks, weak, heated, under - cured, over smoked, opaque and burnt sheets are not permissible. Not even a trace of mould is permitted on the sheets.

2.3 RSS No. 2-Good Fair Average Quality Ribbed Smoked Sheets

The rubber must be dry, clean, strong and free from blemishes, blisters, sand, dirt and any other foreign matter, other than that specified below as permissible.

Slight rust and slight amounts of dry mould will not be objected to, but if present to an appreciable extent on more than 5% of the bales sampled, it shall constitute grounds for objection. Small bubbles and slight specks of bark will not be objected to. Oxidised spots or streaks, weak, heated, under-cured, over smoked, opaque and burnt sheets are not permissible.

2.4 RSS No. 3- Fair Average Quality Ribbed Smoked Sheets

The rubber must be dry, strong and free of blemishes, blisters, sand, dirty packing and all other foreign matter except to the extent specified below.

Slight rust and slight amounts of dry mould will not be objected to, but if present to an appreciable extent on more than 10% of the bales sampled, it shall constitute grounds for objection. Slight blemishes in colour, small bubbles and small specks or bark are permissible.

Oxidised spots or streaks, weak, heated, under-cured, over smoked, opaque and burnt sheets are not permissible.

2.5 RSS No. 4 - Low Fair Average Quality Ribbed Smoked Sheets

The rubber must be dry, firm and free of blemishes, blisters, sand, dirt and other foreign matter except to the extent specified below.

Slight rust and slight amounts of dry mould will not be objected to, but if present to an appreciable extent on more than 20% of the bales sampled, it shall constitute grounds for objection.

Medium sized bark particles, bubbles, translucent stains, slightly sticky and slightly over-smoked rubber are permissible but should not be evident to a marked degree. Oxidised spots or streaks, weak, heated, under-cured and burnt sheets are not permissible.

2.6 RSS No. 5 - Inferior Fair Average Quality Ribbed Smoked Sheets

The rubber must be dry, firm and free of sand, dirty packing and other foreign matter except to the extent specified below.

Slight rust and slight amounts of dry mould will not be objected to, but if present to an appreciable extent on more than 30% of the bales, it shall constitute grounds for objection.

Large bark particles, bubbles and small blisters, stains, over-smoked, slightly sticky rubber and small blemishes are permissible provided they are not present to a marked degree. Slightly under - cured rubber is also permissible.

2.7 SLR 5 (RSS) - (new presentation RSS house types)

RSS No. 1-3 sheets, surface-heated and pressed into small bales and tested strictly according to the SLR scheme, is available in one single grade SLR 5 (RSS) which will conform strictly to all requirements under the SLR scheme. The technical properties of this rubber are given below:

Properties	**Limits**
Dirt % (m/m) (max)	0.05
Ash % (m/m) (max)	0.60
Nitrogen % (m/m) (max)	0.60
Volatile matter % (m/m) (max)	0.80
Initial Wallace Plasticity Number (min)	30
Plasticity Retention Index (min)	60

SLR 5 RSS rubber is packed in 33□kg bales of size 250 x 570 mm or 330 × 670 mm and packed into 1 tonne pallets.

3. GRADING OF PALE CREPE (THICK AND THIN)

Grades from No. IX to No. 3 must be produced from the fresh coagula of natural liquid latex under conditions where all processes are carefully and uniformly controlled. The rubber is creped out in thickness corresponding to the type of sample. No. 4 is produced from fraction rubber while off grades are made from all other coagulated rubber.

3.1 No. IX - Superior thick and thin pale crepe

This form is made by removing approximately 10% of the non-rubber fraction from the latex and by drying in a drying tower and hence is the purest form of natural rubber available in the market.

Deliveries must consist of dry, firm rubber of very light uniform colour. Discolouration, sour or foul odours regardless of cause, dirt specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat, is not permissible. It should dissolve in solvents without forming a gel and hence is most suitable for making products like adhesive tapes by a solution process. Owing to its high purity and the absence of most of the natural proteins it is widely used in the food and pharmaceutical applications and infant toys.

3.2 No. 1 - Thick and thin pale crepe

Manufactured with or without the removal of fraction and hot air drying and hence little gel formation on dissolution is possible. Hence it is most suitable for manufacturing light and bright coloured rubber products by a dry process. This rubber has a higher elasticity and Mooney viscosity than IX crepe. Protein content in fraction removed rubber is lower than in rubber manufactured without removing fraction.

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, dirt specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat, are not permissible.

3.3 No. 2 - Fair average quality thick and thin palish crepe

Deliveries must consist of dry, firm rubber, slightly darker than No. 1. Thick Crepe with slight variation in shade is permissible. Slightly mottled rubber will not be objected to, provided that this condition does not exist in more than 10% of the bales included in the delivery, lot or tender as determined by the number of bales inspected. Discolouration, regardless of cause, dirt specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat are not permissible.

3.4 No. 3 - Fair average quality thick and thin off colour thick and thin palish crepe

Deliveries must consist of dry, firm rubber of off-white or yellowish colour with variation in shade permissible. Mottled and streaked rubber is permissible provided that this condition does not exist in more than 20% 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, are not permissible, other than those specified above as permissible.

3.5 No. 4 - latex thick crepe

Made out of the yellow fraction removed from the latex and hence the non-rubber content is high. Dark yellow or brown in colour. Cause gel formation on dissolution. Produces vulcanizates of high hardness and hence used widely in applications such as in rice huller rollers.

3.6 Off-grade - thick and thin

All thick and thin latex crepe that fails to meet the requirements for International No. 3 thick pale crepe grade will fall into this grade.

4. GRADING OF SOLE CREPE

There are no standards laid down in the Green Book for sole crepe, but from the knowledge of the market, it is possible to spell out the qualities that constitute sole crepe of No. 1 standard and they are enumerated as follows:

Colour	Pale is the ideal white sole crepe, but as this attractive colour is difficult to achieve consistently, buyers accept "Palish"(white is slightly duller than "pale") without reservation as No. 1 standard. "Very slightly yellowish" too can pass muster, but it is a borderline case and if other properties are not of the required standard, then the colour will not by itself justify a No. 1 price. Khaki and brown sole crepe should be very uniform in colour, without streaks, mottling etc. and should not have a foul odour. Coloured sole crepes are also produced on customer requests and they should comply with the other requirements , as given below to be categorized into no. 1 standard
Texture	"Firm" is the correct quality. "Rather Firm" is tolerated, but if allied with a degree of stickiness, then it becomes unacceptable for No. 1 standard.
Surface	This is where many estates fail to achieve consistency. Ideally, the surface must be smooth and uniform in colour with no streaks, oil spots, small stains or specks, or lacy patches. There must not be the slightest trace of roller marks, while blemishes such as pitted areas, indentations and ridges are not acceptable. In the case of pebbly sole crepe, the pebbly nature must be prominent and regular with the reverse side showing hardly any unevenness. Similarly, in the case of ribbed sole crepe the corrugations must be well defined with no impression carried through to the reverse side.
Edges	The cut must be straight (Plate 12.1b). A slight irregularity is tolerated by buyers provided all other aspects fall within the No. 1 standard. "Waviness" is a fault and is not acceptable even when the sheet is perfect in other respects. This defect, when present, is not noticeable in sole crepe of 1/8" thickness.
Lamination	Poor lamination (i.e. the corner of a sheet can be easily split) is a serious defect and is not acceptable in any circumstances.
Thickness	A variation of 1.5 mm (i.e. (1/16") above or below the given thickness is tolerated from sheet to sheet but consistency in thickness enhances the reputation, and therefore the demand for a particular mark. On the other hand, variation within a sheet is a serious defect and could bring about a heavy discount.

The popular thickness range is from 1.65 to 6.5 mm. (Plate 12.1c).

Dimensions: The standard dimensions of sole crepe are 90 cm × 33 cm (36" × 13") but some plantations, on request, can manufacture sole crepe of the size 98 cm × 46 cm (39" × 18").

5. GRADING OF BROWN CREPE (THICK AND THIN)

Brown crepe is made from field coagula commonly known as scrap rubber which consists of pre-coagulated lumps of rubber cup lumps, tree laces or curly scrap and earth scrap. Higher grades of No. 1 to No. 3 are made from lumps and other higher grades of rubber scraps. Tree bark scrap, if used must be precleaned to separate the rubber from the bark. Any of these grades of rubber should not consist skim rubber fully or in part. Depending on the quality of the rubber and the effectiveness of processing of these scrap materials, they can finally be categorized into following grades:

5.1 No. IX – (FAB +) clean light brown thick and thin brown crepe

Deliveries must consist of dry, clean rubber light brown in colour. Discoluration 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, are not permissible.

5.2 No. 2X (FAB) - clean thick and thin brown crepe

Deliveries must consist of dry, clean rubber medium-brown in colour. Discolouration regardless of cause, specks, sand, or other stains, or any evidence of oxidation or heat, strong sour or foul odour, are not permissible.

5.3 No. 3X (FAB-) - brown to dark brown thick and 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, are not permissible.

5.4 Standard flat bark crepe (FB)

The rubber is dry very dark brown to black in colour and is medium hard to soft in texture. Sludge, cotton, sand, dirty packing or other foreign matter, except fine bark particles, are not permissible. Due to rapid deterioration of this grade, no official international type sample has been established. These have been identified in the local trade as off - grade and scrap crepe No. 4.

5.5 Scrap crepe No. 4 (MBC)

Better than standard flat bark crepe but falling short of the requirements for No. 3X thick brown crepe.

6. PACKING SPECIFICATIONS

6.1 Ribbed smoked sheets (RSS)

6.1.1 Conventional packing

- All ribbed smoked sheets should be packed in rubber-covered bales
- The maximum weight of each bale is 100 kg although by agreement between buyer and seller this weight limit can be adjusted.
- Each bale is wrapped on all sides and covered with equal or high quality rubber of the same type.
- Light dusting with talc is allowed to prevent sticking. To overcome adhesion in transit and also to provide a proper background for stenciling of coloured shipping marks, the outside of the wrapper sheet is completely painted on all six sides with a bale-coating solution.
- Bale marking shall appear on two adjoining sides of the bale.

6.1.2 New presentation RSS

The weight of rubber in each bale should be 50 kg or 33□kg. These are pressed bales, usually polythene-wrapped and palletised in one tonne units. The $33^{1}/_{3}$ kg bales resemble TSR bales, but may or may not carry TSR certificates.

The polythene film used for wrapping of bales should be of a quality compatible with rubber when mixed in a 2 roll mill at 110°C. It shall be of 0.05 mm (200 gauge) thickness and shall be colourless. At customers' request wrapping for export may be with 0.1 mm (400 gauge) thick white polythene, in which case the wrapper shall be labeled "strip polythene before use"

6.2 Pale crepe

The standard modes of packing for Sri Lankan pale crepe are described in this subsection. However, special packing to suit customer specifications is always undertaken. For example, thin and thick pale crepe could be packed for shipment in pallets of 1000 kg nett each, consisting of 30 bales of 33 □kg each pre-wrapped in polythene (Plate 12.2a).

6.2.1 Paper bags

4 - ply paper bags with inner ply polythene coated or 4 - ply paper bags with polythene inner wrapper, are used for packing No. IX, No. 1 and No.2 and sometimes No. 3 thick pale crepes in units of 50 kg or 25 kg nett.

6.2.2 Wooden pallet crates

Thick pale crepes from No. IX to No. 3 quality are also packed for export in pallet crates of 1200 kg nett each. Prior to palletizing, each unit is pre -wrapped in 150 - 200 gauge polythene. All six sides of the pallet are also internally lined with 500 - 700 gauge polythene.

6.2.3 Gunny covered bales

This type of packing is generally used for pale crepe grades No. 2 down to "off grades". Specifications are as indicated in the Green Book.

6.2.4 Containers

Sri Lanka pale crepes are also shipped packed in containers.

6.3 Sole crepe

6.3.1 Wooden cases

Packing of sole crepe in wooden cases is not recommended now and hence it is not currently practiced as in the past.

6.3.2 Corrugated cardboard boxes

Sole crepe is packed for export in corrugated cardboard boxes (Plate 12.2b), generally containing 83.33 kg nett each. The sheets within may be interleaved with polythene or grease-proof paper, as required.

6.3.3 Pallet bases

Corrugated cardboard packed cases as described above may be packed in pallet bases in units of 1,000 kg nett each, if required.

6.3.4 Containers

Available for shipment of sole crepe.

6.4 Brown crepe

6.4.1 Gunny covered bales

Brown crepe is usually packed in burlap or gunny covered bales as per the Green Book, each bale weighing 100 kg nett. The bales are usually fully covered in gunny or hessian as per Green Book specifications after strapping with steel bands.

6.4.2 Unwrapped bales

This description refers to bales that are not fully covered but have only two pieces of hessian or light coloured natural rubber on two opposite sides to take on the shipping marks.

6.4.3 Pallet bases

Brown crepe bales of 100 kg nett each packed in the above manner are also strapped on to pallet bases of 1000 kg nett each.

6.4.4 Containers

Available for shipment of brown crepe.

Plate 12.1. Quality inspection and preparation of rubber for packing. **a** Removal of dirt from sheet; **b** Cutting edges of sole crepe; **c** Measuring the thickness of sole crepe.

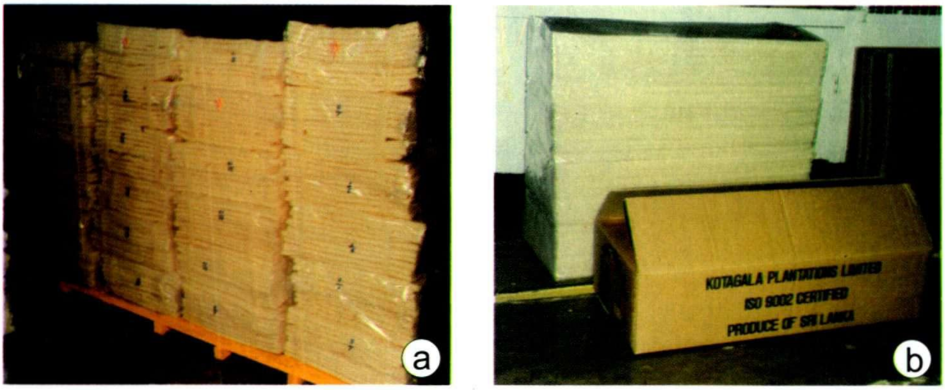

Plate 12.2. Packing of thick crepe and sole crepe. **a** Polythene wrapped thick pale crepe stacked on wooden platform; **b** Corrugated boxes for packing of sole crepe.

Chapter 13

Care and maintenance of rubber factory machinery

W.M.G. Seneviratne and P.P. Jayasinghe

1. INTRODUCTION

The raw rubber manufacturing industry entails a fairly high investment, mostly on heavy machinery and drying towers. Routine maintenance and preventive care of such items is, therefore, very important to avoid breakdowns and incidental losses in production, and high repair costs.

In sheet rubber manufacture, hand – rollers and/or Guthrie batteries of rollers are used while in crepe manufacture, 2 – roll mills of different types, *i.e.* smooth, grooved, spiral, and diamond are used for different levels of milling purposes. Sole crepe manufacture needs laminators whilst scrap rubber needs scrap – washers as well. Technically specified block rubber requires crepers, pre – breakers, hammer – mills, granulators, *etc.*

2. CARE AND MAINTENANCE

2.1 Crepe and sheet rubber machinery

Rubber mills should never be started with a load on as it could burn the fuses and damage the starter switch. At the end of the day's work, the pressure should be released by unscrewing the pressure screws until there is a clearance of 1/16th of an inch at the roller – nip. The following day, mills should be started with a clearance well above 1/16th, and the pressure applied only after inserting the rubber or laces into the rollers, to get the suitable thickness. This procedure should be followed even in a case of power failure. Make certain that the pressure is applied using a Tommy – bar as a lever and not with a hammer.

The most important activity within a preventive maintenance scheme is planned lubrication. It is important to ensure the use of the right type and quantity of lubricant. Moving parts of a machine are not smooth but minutely rough because of inherent characteristics of the machine tools used to make them. During service the surfaces are coated with a film of lubricant. These films must be ruptured before contact can occur between surfaces leading to wear and tear. The rupture of the film of lubricant could be prevented by lubricating regularly. Some mills contain a system for lubricating the pressure screws, in which case, they should be lubricated once a week. In cases where such provision is not made, the pressure screws should be released once a week and grease should be applied into the bush and on the screw. If there is an upward and downward movement of 1/8 of an inch between the pressure screws and the bushes, considerable wear is evident and the pressure screws and bushes need renewal. Properly designed safety pads should be used with the pressure screws, as otherwise there is a possibility of damage to the side frames end gears and journals of the rollers if excessive pressure is used. If an uneven pressure is applied, not only will it give a lace of uneven thickness, but also roll surfaces can become tapered.

The roll bearings should be greased every four hours during the period the mill is in operation. But when the bearings are newly rebushed, for about two weeks till the bearing surface is conditioned, bearings should be greased every two hours. The increased intensity of lubrication may not consume more grease since the gap between the surfaces is less. Inadequate lubrication causes heating of the bearings. It is important to check for any hardened lubricants which will prevent grease getting onto the surfaces.

The end gears should be lubricated with grease daily before commencing work; if not, the wear on the profile of the teeth is accelerated. Bottoming of the end gears is caused by the reduction of the roll diameters and shifting of the centres due to wear. As a result, the top of the gear tooth comes in contact with the root of the teeth on both end gears. This is a serious situation which can result in damaging the side frame or fracture of the roll journals. Roller marks on rubber are also due to this. If bottoming of the end gears is experienced it is time for refacing and grinding of the rolls, skimming and polishing of journals, adjusting end gears to the new roll centres and rebushing roll bearings. It is essential to check the end gear locating key once every fortnight to ensure they are secured.

The driving gear should be lubricated with crater fluids (see list of lubricants). It is essential to check the driving gear locking key monthly to ensure that it is secured. When the teeth of the double helical gears are worn to a knife edge, it is time to replace the set of gears. When the driving spur gear tooth flanks are considerably worn and noisy in operation, the gears are beyond re-use and a new set of double helical gear should be fitted.

The ball bearings should be greased once in two months and the self - oil bearing should be topped up daily. Wear on the lay shaft bearings can be identified if there is approximately 1/8" play when the shaft is levered with a crow bar adjacent to the bearing being tested.

Tension of the belts should be checked regularly and specially if the output decreases. The belts should be free of oil. The water requirements in the mills during latex crepe manufacture is 120 gallons/hr in a macerator or intermediate mill and 160 gallons/hr in a smooth mill. This water is used for cooling the rolls and also to wash off the serum substances and excessive chemicals from rubber. It is essential that adequate water is applied for cooling of the rolls and the internal pipes should be checked for clogging and corrosion at least once a month. If the factory is facing water shortages, the water from the internal cooling system may be recycled after proper cooling. Repairs and replacements should be promptly carried out as there can be discolouration of rubber if excessive heat is generated by the rolls. The water from a two - inch pipe line should not be fed into more than three mills. The spray pipe should be opened before the milling commences.

The motors should be totally enclosed and are normally of the fan - cooled type. For 26″ x 14″ mills a motor of 20 - 25 HP is sufficient.

The factory should keep a separate process line to manufacture scrap crepe since the sand and dirt in the scrap can damage the roller surfaces. The grooved pattern and roll surfaces of the latex crepe line should be inspected periodically. When a new mill or rolls are supplied to the factory they should be used to mill the yellow fraction for about two weeks and conditioned before using for the first fraction. In the process of milling, the most important factor to be borne in mind is to avoid friction in the roller as far as possible specially on the smooth mill. Loose bolts or fixtures of any sort should be tightly secured to ensure they do not fall into the nip of the rolls while in operation and damage the roll surface.

2.2 Drying towers

Drying of crepe rubber is done either in natural air lofts or in drying towers. It is recommended that sole crepe laces and thin lace crepe should be dried only in drying towers. The conventional drying tower consists of a boiler and a series of radiators. For efficient drying the factory officers should carefully monitor the air inlets and outlets of the tower, the frequency and size of firewood charged by the labourers, any leaks in the boiler and radiators etc. It is useful to check the radiators for obstructions every three months. The ash and soot collecting inside the boiler should be removed and the boiler cleaned frequently. The chimney of the boiler should be cleaned of soot every three months. Radiators are cleaned by adding one litre of cutting oil into the main water tank and letting it circulate. The water that is used in the system should be cleaned of suspended material as frequently as possible. The radiator housing compartment should not be used as a store – room for any material.

2.3 Block rubber machinery

Care and maintenance of the TSR (Block) machinery too, could be carried out like the machinery used in crepe manufacture.

The gear – box oil has to be changed every six months. Ball–bearings and racers should be cleaned and regreased every four months. The shredders and breaker blades have to be refaced and resharpened when the machine output becomes significantly low or the current consumption gets high. The oil – filters of the hydraulic presses should be changed every six months. A complete overhaul is advisable at least once a year. The crumb drier nozzles have to cleaned once a month or more frequently. Depending on their performance they have to be replaced annually.

2.4 Latex centrifuging machine

The machine used for concentration of latex is called a centrifuge and special attention should be paid for its care and maintenance. Most of the components of this machine are out of stainless steel and they can be easily dismantled rendering the cleaning of even the deepest interiors possible. Since it uses latex in this process, the machine has to be thoroughly cleaned after every single operation. Other items that need attention are the motor, drive – belt, bearings and anti-vibration – mounts.

The factory management should gather and study all information related to maintenance of every machine and list the maintenance procedure for each. It is very important to maintain records of lubrication and repairs *etc.*

2.5 Safety precautions

This heavy machinery should be equipped with operator –safety measures. These mechanisms range from emergency stop – buttons and bars to cradles. Drive guards and belt – guards are essential. Laminators should essentially have a stop button.

3. TROUBLE SHOOTING GUIDE

Problem	Cause/Remedy
Heating up of roller bearing bushes	• Apply even pressure • Apply sufficient grease of recommended quality • Check water cooling system, both internal and external pipes • Reduce and deepen end gears
Uneven laces	• Apply even pressure • Even out roller surfaces
Pressure cannot be applied	• Aluminium side hopper tongues to be checked and reduced. • Inter-roller bearing block housing clearance to be checked and adjusted. • End gear clearance to be adjusted.
Roller markes on laces	• Clearance of bearing block bushes excessive. • Inter roll end gear profiles to be checked and replaced. • Bull gear drive profiles to be checked. If defect continues after nearing pinion , replacement has to be done.
Mill grinding to a halt	• Check belt slipping • Pressure application to be reduced and reapplied gradually. • Mill being operated full load on resuming after power disruption. • Rating of prime mover insufficient. (initial moving power)

4. RECOMMENDED LUBRICANTS FOR RUBBER MACHINERY COMPONENTS

Phosphor bronze roller bearings and layshaft bearings - Multifac MP 02 or Molytex EP

End gears and double helical gears - Crater Fluids 338

Racers/Bearings - Multifac EP

Cutting oil for drying tower boiler and radiators - P 282 Lanka Cutting oil

Industrial gear oil for torque arms and gear boxes - P 386 Merupa

Transformer and switch gear oil - Transformer oil BS1

Chapter 14

Energy consumption and conservation in raw rubber manufacture

W. M. G. Seneviratne

1. INTRODUCTION

Almost all rubber factories operate on low-tension electricity supplied via step-down transformers fed by the national power grid. This power is used to run the motors of various rubber processing machinery. However, the power supplied to the factory cannot be utilized fully mainly due to two reasons, i.e. losses and wastage. Wastage is consumption of energy which serves no purpose and is mainly due to mishandling or oversight. It is avoidable and can be eliminated from the system if necessary precautionary steps are taken. Some examples of wastage are: pilferage, spillage, leakages, burning unwanted lights, over/under–illumination of surroundings, idling of machines/equipment and use of over-size machines. Losses are those associated with the technological process and are normally inevitable and are inherent features of the system. However, losses may become excessive or beyond tolerable limits, due to drawbacks in the technological processes or the equipment in which the processes take place. Then that portion of the losses which are above the unavoidable limit would be considered as wastage. Power losses by way of heat generation through the body of equipment such as working mills, engines and presses are known as body losses.

Heat energy is wasted by way of flue/exhaust gases, inefficient combustion, poor quality fuel, wet firewood, heavy oil without pre - heating, electrical line losses, e.g. low power factor boilers, dryers, furnaces, kilns, etc.

The measures described in following sections could be adopted to increase the efficiency of usage of electricity.

2. POWER FACTOR CORRECTION

Electrical power is used by various electrical equipment such as heaters, motors, fans, and lights. The electrical power used by such equipment comprises two components:

- Active power (kW): This produces useful work ranging from providing motive power to industrial machines to lighting an electric bulb.
- Reactive power (kVA_r): This produces the magnetic field necessary to operate electrical machinery.

The active power and reactive power requirements vary with the size of the equipment and the type. The horsepower or kW of equipment indicates the active power requirement and this depends on the size of the equipment and its output.

Normally, electrically driven motors require additional current for magnetizing purposes in starting. This additional power required is called reactive power (I_r- KVA_r). In addition, motors require power for their operation. This power is called active power (I_{ac}- KWH). The ammeter always shows the operating or apparent current (I_{ap}- KVA) which is the sum of reactive and active current, i.e. total power. Active power is the component useful to us. Nevertheless, a reading on the ammeter always shows the operating current (apparent current- I_{ap}- KVA- Total Power) which results from the sum of the reactive and active currents.

The Demand charge (charge levied on total power consumption) is a considerable proportion of the total electricity bill and this could be reduced considerably by improving the power factor of the electrical system. Either fixed capacitors or variable capacitor banks can be used for power factor correction and improvement. The power factor can be corrected upto 0.98 with a centralized automatic capacitor bank. The automatic capacitor unit is connected to the main distribution panel whereas fixed capacitors are connected directly to the motor.

Power factor (PF) is given by the ratio of useful current to the total current. It is also the ratio of useful power expressed in kW to total power expressed in kilowatt-amperes (kVA). Power factor is usually expressed as a decimal number or a percentage.

$$\text{PF} = \frac{\text{Useful Power (kW)}}{\text{Total Power (kVA)}} \quad \text{e.g.} \quad \frac{60\text{ kW}}{100\text{ kVA}} = 0.60$$

A low power factor means that the equipment uses more reactive power to give the same amount of active power or output.

2.1 Benefits of power factor improvement

Benefit No. 1: Total power (kVA) would become low for the same working power (KW) of a plant. Therefore, the demand charge which is a substantial component of the total electricity bill would be reduced considerably. Monthly electricity bills consist of the energy charge and the demand charge. Therefore savings from reduced demand with improved power factor will be very significant. Table 14.1 illustrates the reactive power and the transformer capacity requirements for an installation with 800 kW working power.

Table 14.1. Transformer capacity (KVA) required for a fixed load of 800 kW under different power factors

Power Factor	0.6	0.7	0.80	0.9	1.0
Real Power (KW)	800	800	800	800	800
Reactive Power (KVAr)	1067	816	600	387	0
Total Power (KVA)	1333	1143	1000	889	800

Benefit No. 2: Working power kW would become more for same KVA capacity. One could view power factor improvement from another angle. Power factor improvement will enable the installation of additional machinery without increasing the transformer capacity. Table 14.2 illustrates this phenomenon.

Table 14.2. Useful power of a 800 KVA supply transformer under different power factors

Power Factor	0.6	0.7	0.80	0.9	1.0
Real Power (KW)	480	560	640	720	800
Reactive Power (KVAr)	640	571	480	349	0
Total Power (KVA)	800	800	800	800	800

Benefit No. 3: Voltage regulation of the power system would become improved due to reduced line voltage drop. This benefit will result in more efficient performance of motors and other electrical equipment.

Benefit No. 4: Capacity requirements of the transformers would be reduced with improved power factor. Therefore, investment for installation of smaller capacity transformers with required cables, switch gears etc. would become significantly reduced.

Benefit No. 5: Power loss in distribution systems would be reduced with improved power factor of the electrical system.

Percentage reduction in power loss is given by the following formula.

$$\% \text{ reduction in power losses} = 100 - 100 \frac{(\text{Original PF})}{(\text{New PF})}$$

2.2 Types and selection of capacitors

The load in a typical industrial installation changes virtually every instant. As a result, the amount of kVAr to be provided externally to maintain a desired power factor also changes with the changing kW demand. Although it may be technically possible to provide the correct amount of kVAr to follow the load curve so as to maintain a fixed power factor, it is generally uneconomical to do so, unless capacitors are installed into the circuits.

2.3 Fixed capacitors

Power factor correction capacitors are commercially manufactured to provide a fixed quantity of reactive power (e.g. 5kVAr, 10 kVAr, 50 kVAr, etc.). In some situations, installing a fixed capacitor may suffice to improve the power factor to an adequate level. For example, fixed capacitors are often recommended for individual machines such as motors or installations exhibiting relatively steady demands. One should, however, exercise caution in selecting the correct rating of fixed capacitors as a higher rating than necessary (over compensation) could lead to problems.

2.4 Automatic capacitor banks

In some situations, fixed capacitors may not provide the necessary correction. A bank of capacitors with the facility to "sense" the reactive power demand and provide the right amount of reactive power (by connecting to the required number of capacitors) is more appropriate in such situations. This method obviously is more expensive than installing a fixed capacitor as additional switching circuits are involved. Switched capacitor banks however, are superior in performance as they could "follow" the load curve closely (provided capacitor selection is done carefully).

2.5 Measurement of power factor

Two methods are commonly used to measure the power factor in a factory.

Method I - Use of Clip-on type power factor meter

Direct readings of power factor could be obtained with Clip-on type meter. In the case of measuring power factor of the whole installation or a sub section, several readings should be obtained. The power factor at the highest loading and at several other intermediate loadings should be noted.

Method II - Use of supply authority meters when a kWH meter and a kVA maximum demand meter with kVAH dial is available

Overall average power factor over a given period of operation can be worked out by noting the readings given below.

Reading on kWH meter dial at the beginning of the period – kWH 1
Reading on kWH meter dial at the end of the period – kWH 2

Reading on kVAH meter dial at the beginning of period – kWAH 1
Reading on kVAH meter dial at the end of period – kWAH 2

$$\text{Average power factor during the period} = \frac{\text{kWH 2} - \text{kWH 1}}{\text{kVAH 2} - \text{kVAH 1}}$$

2.6 Important guidelines in connecting power capacitors

- The most economical location is directly across the terminals of larger motors thereby eliminating the cost of a separate switch. The capacitor rating will depend on the horsepower rating and speed of the motor. These capacitor ratings normally correct the nonloaded motor power factor to unity which in turn generally results in a full - load power factor of about 96%.
- Where there are multiple motors of small horsepower rating, or motors which do not run continuously, the capacitors should be connected at the supply point to the factory through an appropriate switching device to serve as a relay for servicing or to operate at light loads.
- Installation may be done at load centres, when it is difficult to connect the capacitors directly across motor terminals or to feeders. Again, switching is a recommended practice.

3. DEMAND CONTROL THROUGH LOAD RESCHEDULING

Significant reductions in the electricity bills can be achieved by avoiding the operation of all machines at the same time and rescheduling operations where possible. There is a possibility of reducing maximum power demand of an electrical installation by properly scheduling the operating times of the electrical loads in such a way as to avoid the occurrence of high kVA peaks of short duration during operation. In other words, it would be advantageous to schedule the electrical loads, so that the power demand pattern would be nearly uniform. This would relieve the factory of paying unnecessary kVA surcharges.

By operating the factory to achieve electrical loads according to a well planned schedule it would be possible to maintain uniform kVA demand pattern and reduce the kVA surcharges.

The following procedure is suggested, in order to maintain the maximum power demand at a uniform level and to minimize it if possible.

- Record kVA values over a specified period of time during operation.
- Draw a graph of kVA values taken at close intervals (e.g. every 15 min) versus time.
- If peaks are observed in this graph, avoid unnecessary electrical operations during these periods, which could otherwise be done during non-peak hours.
- Take adequate steps to restructure the manufacture/processing operations without affecting the day's production level.
- Demand management – Limit unnecessary start-up operations of the equipment/machinery during this period under evaluation.

4. USE OF EFFICIENT MOTORS

Electric motors account for about three quarters of the total electricity consumption in the rubber industry. Therefore, use of motors in a factory should be managed efficiently.

4.1 Motor idling

Motor idling is a very common feature of industrial usage leading to a situation that could be prevented. Depending on circumstances, up to 50% full load current may be taken up by motors when no real work is being done. Hence, production should be planned to avoid of motor idling as much as possible.

4.2 Replacing a motor

A motor may have to be replaced because it has burnt out or due to renovation or expansion.

When replacing a motor, the first step should be to verify whether the old one was of correct size and horsepower. Oversized motors will operate at reduced efficiency and low power factor. Obviously, any new motor, whether or not it is a replacement, should be the right size for the intended use. It is left to professionals to determine the motor size that is appropriate. Rewinding of burnt motors often reduces their efficiency and it is therefore not recommended to use them continuously.

4.3 Rewinding of motors

Rewinding of a burnt motor often reduces its efficiency. Therefore great care should be taken to ensure that rewinding is carried out to the highest standards to get the same level of performance as the original. When energy costs are considered, it is often a better to invest in a new high efficiency motor.

4.4 High efficiency motors

New motors are available in standard and high efficiency models. A high efficiency motor will cost more than a standard one, but the saving on electricity will offset this cost difference in a short period. Efficiencies of standard and efficient motors and a cost/benefit analysis for replacing a 20 HP motor with an efficient one is given below.

4.5 Cost/benefit analysis for efficient motors

Replacement of a 20 HP standard motor with a 20 HP energy-efficient power motor.

Motor Rating	20 HP	
Mechanical Load	85% of rating.	
User's schedule	6 hours per day and 6 days per week.	
	=	1872 hours per year.
Electricity use/hour	**=**	**Horsepower × load × kW/hp + efficiency**
Standard motor		
Normal efficiency	=	87%
Electricity use/hour	=	20 × 85% × 0.746 +87%
	=	14.57 kW
Efficient motor		
Normal efficiency	=	90.5%
Electricity use/hour	=	20 × 85% × 0.746 +90.5%
	=	14.01kW
Saving/hr	=	14.57 – 14.01 = **0.56 kW**
Saving /year	=	1048.32 kW.

5. ILLUMINATION

Illumination is perhaps the most noticeable cause of energy waste in many organizations and there are indeed many opportunities for reducing energy costs, ranging from simple manual switching off to upgrading of lights to more efficient types. Applying lighter colours to interiors of buildings would improve the light intensity whereas dark colours absorb light.

The benefit of natural light must not be ignored and advantage should be taken of, where possible. The level of natural light does vary due to weather and time of the day. Supplementary artificial light is normally required to maintain adequate light levels. These should be controlled to maintain a reasonably adequate level of illumination within the building. Systematic maintenance and the quality of replacements of the equipment at the end of its life span are also important to reduce power consumption. The interior lighting could be made efficient with fluorescent and/or compact fluorescent lights for office areas, and sodium vapour or fluorescent for exterior lighting.

Staff can play an important part in controlling use of lights and this is to be encouraged as part of an organization's energy efficiency image. Staff should be encouraged to switch off equipment not being used.

6. SYSTEMATIC MAINTENANCE

Systematic maintenance is essential to achieve the efficiency of the internal network. A scheme should be drawn up for this purpose and replacements should be done with quality spares at the end of the recommended life span. This is specially applicable to the illumination system.

The electrical network should be maintained in a satisfactory condition. This will include balancing of phases to reduce neutral current and improvement to the existing wiring. Accurate records of electricity consumption, maintenance data etc. are most essential to maintain the same level of high efficiency at all times.

7. FIREWOOD AS FUEL

Firewood is the only fuel used for boilers which provide heat for rubber-drying towers. Even though a substantial replanting cycle is carried out in rubber estates, a scarcity of rubber wood is apparent, mainly because of its value as a quality timber when boron-treated. Hence use of firewood should be done efficiently.

Moisture content of the fuel wood has a direct effect on its calorific value.

	Moisture content	Energy
Wet timber	40%	12kW
Partially dried timber	20%	15kW
Dry timber	8%	20kW

Hence it is always important to use dry firewood chopped into small pieces. Attention should be given to

i. Maintenance of the boiler and radiator system,
ii. Use of excess or piled up firewood inside the boiler and
iii. Insulation of the boiler surfaces.

It is always advisable to insert laces or sheets into drying chambers with reduced moisture content. If initial moisture content can be reduced by 1%, this will increase the drying rate by 10% approximately.

In general, to dry 1 kg of RSS 0.8 kg of dry firewood is required where as to dry 1 kg of crepe rubber 0.2 – 0.3 kg of dry firewood is adequate.

Chapter 15

Rubber factory waste water treatment to prevent environmental pollution

W.M.G. Seneviratne and W.M. Thurul

1. INTRODUCTION

Natural rubber plays an important role in the economic development of all NR producing countries. However, the industry also contributes to industrial pollution in rubber growing areas mainly due to discharge of untreated effluent into the surroundings.

During the primary processing of raw rubber and in the manufacture of rubber products, large quantities of effluent are generated. The main effluent from raw rubber producing factories is rubber serum and processing water. Field latex contains about 30-40% rubber dispersed in an aqueous phase. Rubber hydrocarbon is separated by acid coagulation during processing of field latex and the aqueous phase containing dissolved organic matter such as proteins, amino acids, carbohydrates, inorganic salts etc. goes into the liquid sediment which is called rubber serum. Serum water which leaves the factory together with the washings from the raw rubber milling process and the combined contaminated water is known as rubber factory effluent. The cumulative overall organic pollutant level of effluents in the serum water is measured in terms of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) and other effluent quality parameters. Small rubber particles, uncoagulated latex and traces of process chemicals are also present in the serum water.

There are over 160 raw rubber processing factories producing mainly crepe rubber, sheet rubber (RSS), technically specified rubber (TSR), and centrifuged latex scattered throughout the rubber growing areas of Sri Lanka. The nature of the effluent depends very largely on the type of raw rubber manufactured and effluents from centrifuged latex production contains the highest concentration of undesirable non-rubber constituents.

Average effluent quality parameters of effluent generating from various types of rubber processing are given in the table 15.1 along with the regulatory standards prior to disposal of effluent stipulated by the Central Environmental Authority (CEA) in Sri Lanka.

Table 15.1. Average effluent quality parameters of effluent generating from various types of raw rubber

Parameter	**RSS**	**Crepe**	**TSR**	**Latex Concentrate**		**Dipped products**	**Tolerance limits**
				Ave.	Skim		
pH	4.9	5.0	5.7	3.7	4.5	7.2	6.5-8.5
C.O.D.	3300	3500	2740	6201	25000	2011	400
B.O.D.	2630	2500	1747	3192	-	1336	50/60*
Settlable solids	50	45	155	100		200	
Suspended solids	140	130	237	190	1000	241	100
Total solids	3745	3500	1915	7576	13000	2457	1500*/1000
Ammoniacal Nitrogen	75	80	66	401		126	300*/40
Total nitrogen	500	550	147	616	900	180	300*/60
Sulphates		374		1610	11300** 3800***	72	1000
Sulphides		15					2
Sulphites		190					

All figures are in mg/l. except pH

* CEA standards Centrifuged latex processing effluent

** Skim effluent when skim latex is coagulated with sulphiuric acid

*** Skim effluent when skim latex is coagulated with formic acid

An average size crepe rubber factory processes 1500 - 2500 kg of raw rubber per day and discharges approximately 40 – 50 litres of effluent for every kilogram of rubber processed. It is estimated that about 3 – 4 million tonnes of effluents per year are produced by these rubber factories. Crepe rubber processing contributes to a major part of this.

The common practice in Sri Lanka with regard to rubber serum disposal has been to discharge it through a suitable drain into the nearest stream (Plate 15.1a). If sufficient free oxygen is supplied by aeration or dilution, aerobic bacteria take up the burden of purification of pollutants by aerobic degradation. In dry seasons pollutants accumulate in water bodies. The action of aerobic bacteria that decompose organic matter is reduced with a diminishing oxygen supply. After the dissolved oxygen has been exhausted the anaerobic bacteria utilize organic pollutants. This anaerobic degradation process gives rise to obnoxious gases such as hydrogen sulphide and volatile malodorous organic molecules.

In Sri Lanka prolonged dry seasons cause environmental problems in most rubber growing areas. Further, almost all the factories receive complaints to the effect that effluents discharged from them are causing water pollution problems. This has been clearly recognized by environmental authorities in Sri Lanka and all other NR producing countries. At the same time public awareness on environmental issues has increased and legislation on water pollution control has been introduced and become more stringent at present and steps are taken to implement appropriate and acceptable measures.

2. WASTE WATER TREATMENT

The major pollutant, dissolved organic matter, of rubber factory effluent is highly biodegradable. Hence any biological waste water treatment methods such as Oxidation Ditch, RBC and Activated sludge system (Plate 15.1b and 15.1c) can be applied for treatment of rubber waste water as well. Anaerobic/ facultative ponds have been commonly used in many rubber processing countries for the treatment of rubber effluents in the past, however they seized to be in existence presently due to the very large space requirement and mal odour problems (Plate 15.1d and 15.1e) In biological wastewater treatment, a large amount of active microorganisms is maintained in a specially constructed environment. Waste water is supplied to the microorganisms as food while providing the other conditions necessary for their activity. The type of microorganisms in the system could be aerobic, anaerobic or both and could be maintained in suspended, fixed or both forms. Different waste water treatment systems may vary from one to another according to the type or the form of microorganisms maintained in the system.

2.1 Some developments in waste water treatment

In order to overcome the limitations inherent in standard treatment technologies, RRISL made several appropriate developments, enabling cost-effective biological treatment of rubber factory effluents. These developments can be applied for treating biodegradable waste water emanating from other industries as well.

2.1.1 Coconut fibre-based bio-brush media

The possibility of using coconut fibre as a medium for high-rate biological waste water treatment underlies most of the appropriate developments presented in this text. Coconut fibre (Plate 15.2a) is superior to the other materials used for this purpose around the world in terms of efficiency and cost. Using coconut fibre as the base material a variety of configurations of media for biological treatment processes is possible. Bio-brush media are one recommended configuration of coconut fibre-based media out of many possibilities.

Bio-brush media are designed and manufactured to optimize the biological activity of any kind of biological liquid waste treatment reactor. With the use of this the required volume of a treatment system is minimized. Bio-brush media can be fixed in any shape of reactor or any tank configuration built to suit the available site. The surface is highly capable of retaining active biomass and with the recommended arrangement, the medium is highly porous avoiding self-clogging. This medium is capable of presenting a high surface area per unit volume, occupying a small fraction of the reactor. By using bio-brush media for biomass holdup, a variety of biological treatment reactors of aerobic, anaerobic, or anoxic nature can be operated effectively and efficiently, depending on the treatment requirement.

Bio-brush media are particularly suitable for use in anaerobic treatment. When properly used bio-brush performs extremely well in anaerobic reactors and treats waste water meeting CEA standards by anaerobic treatment alone even at high loading rates, eliminating the historic requirement of aerobic treatment after anaerobic treatment of wastes with high concentrations of pollutants.

2.1.2 Coconut fibre-based in situ odour filter

This new filter is also biologically activated. It eliminates odour emissions on the spot effectively. The problem of odour emissions from wastewater treatment facilities is seldom addressed even in developed countries, mainly because of the high extra costs involved. This new odour control technology costs much less than the available technology around the world.

By using this development, it is possible to achieve high standards of environment friendly management of rubber waste at low cost.

2.1.3 Covered activated ditch reactor

This is a low-cost reactor configuration and is a further improvement over the well-known low-cost pond process. It is an accelerated pond process and the acceleration is done by using the bio-brush medium (Plate 15.2b). The pond is made up of a number of ditches, of which the average depth, width and length are 1 m, 1 m and 30 m respectively. This overcomes many inherent drawbacks of the pond process, including the requirement of large extent of flat land, while preserving its low cost as the main advantage. The process is very versatile and although this is a form of pond process, it can be set up even in hilly lands and under most topographic conditions.

The operation of the ditch is normally facultative/aerobic at the top layer and anaerobic underneath the top layer continuing to the bottom of the ditch. Where applicable it is also possible to activate the ditch by circulating the water by using a series of jet aerators.

2.1.4 Covered activated honeycomb reactor

This is also a comparatively low-cost reactor configuration, which is particularly suitable for package treatment systems where bio-brush media are used for biomass maintenance. The strategy of construction is derived from a beehive, but the reactor chambers are critically sized for packing bio-brush media for optimum efficiency.

2.1.5 Facultative polishing filter ditch

A coir-filled shallow ditch is used as a polishing ditch for further treatment of anaerobically treated waste. The average depth is about 0.5 m. Aquatic plants are allowed to grow on the top of the coir layer and the upper area is more aerobic while further below it is anaerobic. It greatly reduces the suspended particles and any remaining dissolved organic matter.

2.1.6 Diffusive activated biological screen - rubber trap

This rubber trap was developed in order to minimize the entry of uncoagulated rubber particles to the main section of the treatment system where degradation of dissolved organic matter takes place. A considerable amount of uncoagulated rubber particles pass through conventional rubber trap units, creating unexpected clogging problems. In this new rubber trap, rubber factory effluent flows through a series of biologically activated perforated baffles/screens, which are best made of coconut fibre. Biological activity at the baffle produces and diffuses organic acids and enzymes, which react with uncoagulated rubber particles and destabilize them. Destabilized rubber particles agglomerate, float to the top and get trapped. The biological screens tend to get clogged after a certain period of operation depending on the nature of the waste treated and should be removed when clogged.

2.2 A Cost effective treatment system for waste water based on high rate anaerobic/aerobic treatment methodology

The treatment system recommended for rubber factory waste and similar industrial effluents is based on anaerobic and aerobic microbiological process and comprise the following stages (Plate 15.2c):

i. Particulate matter trap stage
ii. Anaerobic stage

iii. Aerobic stage
iv. Sludge settling stage
v. Filtration stage

2.2.1 Particulate matter trap tank

In rubber factory waste water, about 1% of uncoagulated rubber comes along with the effluent initially and could be separated from the mainstream of effluent by allowing it to travel in a staggered pathway. The tank built for this purpose should have the capacity to allow the effluent to be retained for approximately 8-12 hours per day and comprise of few compartments (Plate 15.2d). Most rubber particles tend to float on the surface during travel through the compartments.

2.2.2 Anaerobic digester septic tank

The digester is a rectangular enclosed tank with a few vents. It is designed to cater to two days' effluent retention. This tank is partitioned into at least five compartments and effluent is allowed to travel along the longest path possible within these compartments. The tank is filled with rubberized coir cuttings packed in a systematic manner (density approximately 0.5 g/ml, porosity 80%) upto 2 m height. Appropriate mesh is incorporated in each compartment of this tank to prevent floating of the coir matrix on the water surface. The depth of the tank preferably be above 3 m (Plate 15.2e).

2.2.3 Aerobic digester tank

The effluent coming out from the anaerobic digester tank is allowed to overflow into this tank which is of rectangular shape. Diffused or surface aeration could be employed by means of submersible or surface aerators. The capacity of the tank is designed to accommodate one full day's effluent with 2.5 m depth and aerators should be capable of supplying oxygen at a rate of approximately 1.5 kg of O_2/kw/hour (Plate 15.1c , 15.2f).

2.2.4 Sludge settling/clarification tank

This could either be a circular or rectangular tank but the bottom is an inverted cone deepest at the center (Fig 15.1). It is also equipped with a cylinder mounted in the middle of the tank. Aerobically treated effluent is allowed to overflow into this tank through the cylinder and it is designed to retain the effluent for approximately 6 hours. The height of the fluid in the tank is maintained at 2.5 m to 4 m at the center.

2.2.5 Sand bed filter tank

The tank is of rectangular shape and partitioned into two compartments. The first compartment is relatively large and is packed with sand and stones of varying sizes in such a way that sand is at the top followed by stones in ascending order of size towards the bottom. The height of the tank is approx. 2.0 m and the filtered effluent is discharged from the top of the second compartment (Fig. 15.1).

2.2.6 Start up operating procedure

In any biological treatment process it is quite vital and important to have adequate quantities of both aerobic and anaerobic bio-mass in the respective digestive tanks prior to the commencement of the operation of the plant. Therefore, special attention has to be paid to build up the microorganism level in digester tanks initially. This could be done as follows;

2.2.6.1 Anaerobic digester

During the start up operation, anaerobic sludge (upto 1/4th of the tank) obtained from another plant should be placed in the anaerobic tank. The rest of the volume is filled with water. Afterwards effluent obtained from a latex coagulation tank of which COD is approximately 10 kg/m^3 could be sent to the anaerobic tank for 2 – 3 weeks at the rate of 0.9 kg/m^3/day. After a period of 1 month MLSS (Mass Liquor Suspended Solids) of the anaerobic digester would usually rise up to a level of around 6.00 kg/m^3 and appear to have reached a steady state. This level of bio-mass would be sufficient to start up operation of the anaerobic digester for the treatment of the total quantity of effluent discharge.

2.2.6.2 Aerobic digester

Approximately a quarter of the of the capacity of the tank should be filled with activated sludge (MLSS = 6 kg/m^3) obtained from another effluent treatment plant and the rest of the tank is filled with fresh water and fresh serum to approximately 1/10 of the capacity of the tank. A similar quantity of serum effluent is then required to be sent to this tank daily while aerating until the aerobic bio-mass of the tank rises up to a level of approximately 3 kg/m^3 . This could usually be achieved in 3 weeks time and remains unchanged during the operation of the plant.

2.2.7 Microbial degradation of organic materials in the process

Bacteria play a key role in biological wastewater treatment processes as described in earlier subsections. Different species of bacteria are involved in the treatment mechanism and each species has its specific functions and characteristics. In the anaerobic digester tank the waste is degraded by anaerobic bacteria. The tank has a plug flow configuration in which the fluid that enters the tank is discharged in the same sequence in which they enter. In this plug flow digester septic tank the conversion of the waste into breakdown products results in a substrate gradient in the tank. The bacteria are retained in the digester tank by fixation to the coir mats. Without such a fixation of bacteria, the very slowly growing anaerobic bacteria might be washed out of the tank if undesirable conditions occur in the tank, e.g. pH<6 and also due to continuous fast flow of the liquid. The biological conversion of the organic matter in the anaerobic septic tank takes place in three steps namely Hydrolysis, Acedogensis and finally converting organic materials to biogas at the Methanogenesis process. Biogas is a mixture of methane, carbon dioxide and hydrogen sulphide. The biogas forms bubbles in the tank and is finally emitted into the atmosphere.

After operating the anaerobic digester for approximately one month with the proper start up technique as described earlier the level of treatment could easily be maintained at 70-85% organic removal rates at most organic (food) loading levels. Rapidity of the start up of the anaerobic digester septic tank could be attributed to balanced nutrients of the effluent for the development of microorganisms, particularly methanogenic bacteria. Rapid start up of the digester is also an indication of the rapid attachment of the anaerobic bacteria to the rubberized coir.

After anaerobic treatment the rest of the undegraded organic matter is subjected to aerobic degradation in the aeration tank. The aerobic process will oxidize the carbonaceous compounds and convert ammonia formed from the digestion of nitrogenous compounds into nitrogen through nitrification and denitrification processes taking place in the aerobic tank.

2.2.8 Advantages and cost effectiveness of the technique over the conventional treatment systems

Anaerobic digestion of the treatment process mostly yields a very high organic removal rates usually resulting over 85% treatment at most organic loading rates within only two days retention in the digester. This is mainly because of the higher bacteria fixation levels on the coir carrier matrix. Conventional anaerobic digesters usually requires much higher retention periods to achieve same treatment. However, efficiency of removal of organic matter in the aerobic digester is usually low. This is the result of very low loading rates into the aerobic digester after a highly successful anaerobic treatment. Loading rates could only be maintained at a range between 0.13 – 0.23 kg/m^3/d and the observed level of removal rates is in the range of 45% at an average.

Generation of sludge at the aerobic stage is very low and hence disposal of sludge becomes simpler than in most conventional aerobic treatment processes. This is due to the very high removal rates achieved at the anaerobic stage. However, sludge formed was highly settlable and could be well separated in the clarification stage.

Rubberized coir is found to be extremely resistant to degradation when submerged in water and hence it can even last more than 6 years without any detrimental effects. As a result of high removal rates at the anaerobic digestion stage, requirement of aeration becomes very minimal in the aerobic digester and hence cost of electricity for aeration is very low. Performance efficiency of the plant is always high without much attention and the effluent quality of the final discharge complies with the standards of the Sri Lanka Central Environmental Authority.

Due to high practical nature and cost effectiveness of the treatment system, it had already proven its economic viability and easy adaptability in the country. Large number of commercial scale treatment plants has already been installed in rubber processing factories in the country.

Figure 15.1 gives the general schematics of the process of waste water treatment.

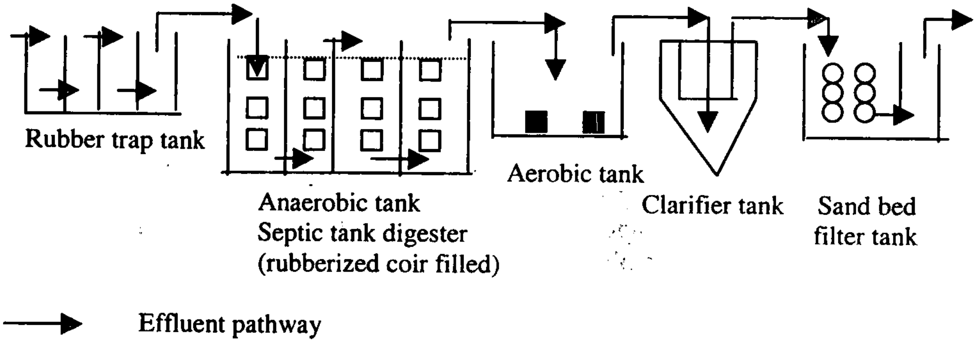

Fig. 15.1 Schematic diagram of the treatment plant

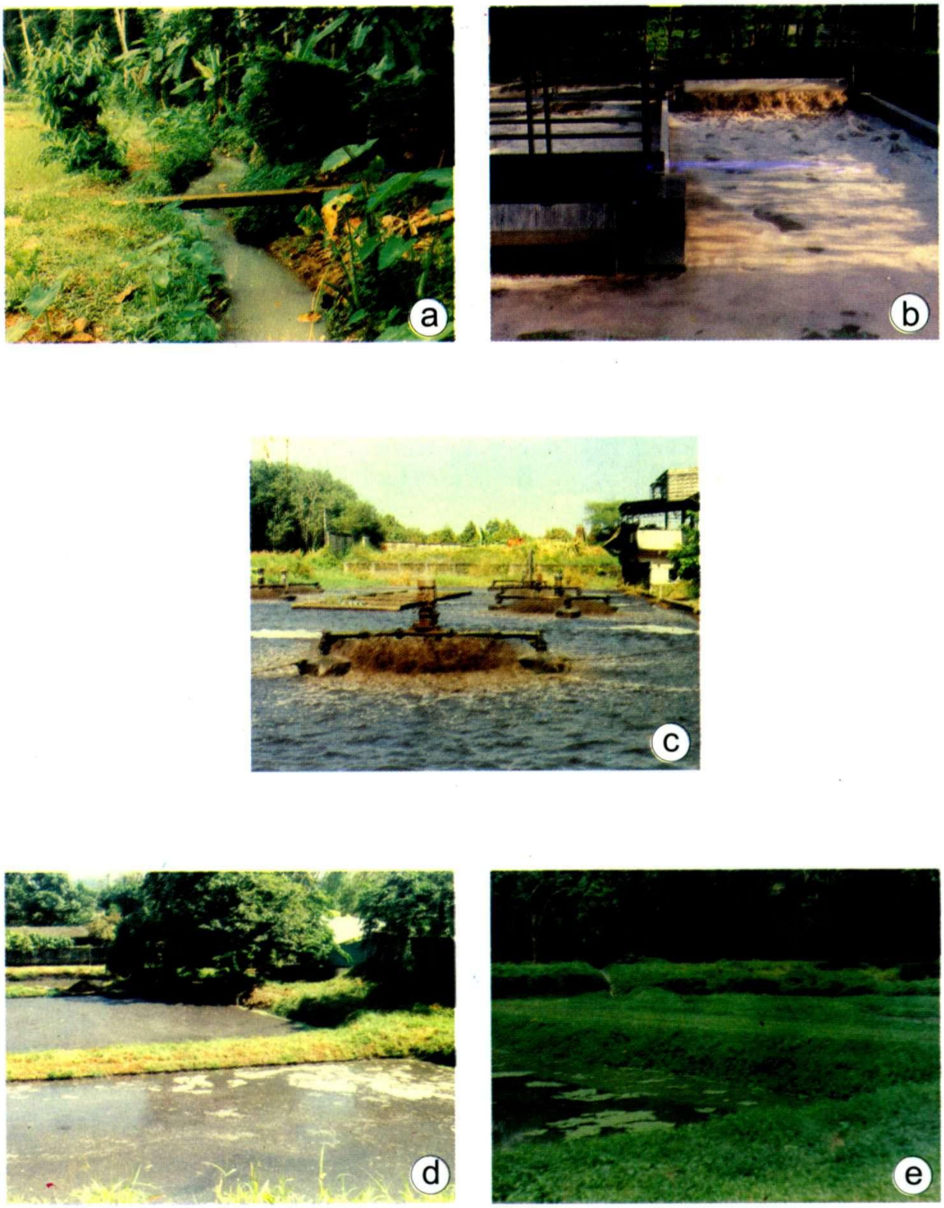

Plate 15.1 **a** Discharge of untreated effluent in to surroundings; **b** Oxidation ditch treatment process used in a concentrated latex processing plant; **c** An activated sludge aerated lagoon treatment process in a TSR factory; **d** Anaerobic/facultative ponds in a latex concentrate factory; **e** Final alga rich polishing pond of the series of anaerobic/facultative ponds.

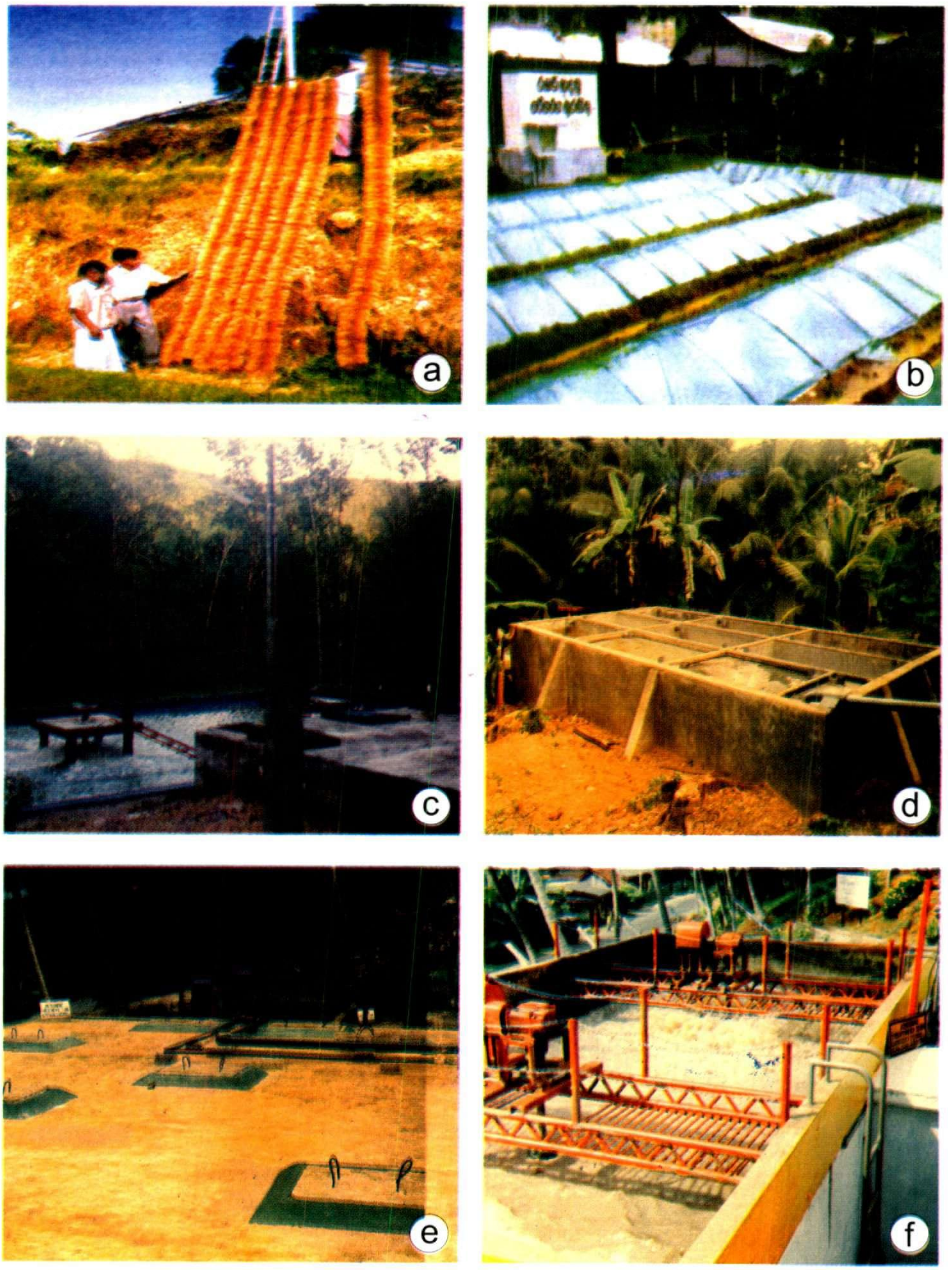

Plate 15.2. **a** Coconut fiber brushes in the treatment reactor; **b** Ditch reactor; **c** A cost effective treatment system for waste water based on high rate anaerobic/aerobic treatment methodology; **d** Rubber trap tank; **e** Rubberized coir cuttings filled enclosed anaerobic digester; **f** Aerobic digester tank fitted with two surface aerators in a crepe rubber factory.

ANNEX I

The standard metrolac chart

(Dilution: 1 part of latex to 2 parts of water)

METROLAC → READING	50	60	70	80	90	100	110	120	130	140	150
Volume of Latex (Litres) ↓	↓ Weight of rubber in kilograms										
1	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
2	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.76	0.80
3	0.60	0.66	0.72	0.78	0.84	0.90	0.96	1.02	1.08	1.14	1.20
4	0.80	0.88	0.96	1.04	1.12	1.20	1.28	1.36	1.44	1.52	1.60
5	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
6	1.20	1.32	1.44	1.56	1.68	1.80	1.92	2.04	2.16	2.28	2.40
7	1.40	1.54	1.68	1.82	1.96	2.10	2.24	2.38	2.52	2.66	2.80
8	1.60	1.76	1.92	2.08	2.24	2.40	2.56	2.72	2.88	3.04	3.20
9	1.80	1.98	2.16	2.34	2.52	2.70	2.88	3.06	3.24	3.42	3.60
10	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
11	2.20	2.42	2.64	2.86	3.08	3.30	3.52	3.74	3.96	4.18	4.40
12	2.40	2.64	2.88	3.12	3.36	3.60	3.84	4.08	4.32	4.56	4.80
13	5.20	5.72	6.24	6.76	7.28	7.80	8.32	8.84	9.36	9.88	10.40
14	2.80	3.08	3.36	3.64	3.92	4.20	4.48	4.76	5.04	5.32	5.60
15	3.00	3.30	3.60	3.90	4.20	4.50	4.80	5.10	5.40	5.70	6.00
16	3.20	3.52	3.84	4.16	4.48	4.80	5.12	5.44	5.76	6.08	6.40
17	3.40	3.74	4.08	4.42	4.76	5.10	5.44	5.78	6.12	6.46	6.80
18	3.60	3.96	4.32	4.68	5.04	5.40	5.76	6.12	6.48	6.84	7.20
19	3.80	4.18	4.56	4.94	5.32	5.70	6.08	6.46	6.84	7.22	7.60
20	4.00	4.40	4.80	5.20	5.60	6.00	6.40	6.80	7.20	7.60	8.00
21	4.20	4.62	5.04	5.46	5.88	6.30	6.72	7.14	7.56	7.98	8.40
22	4.40	4.84	5.28	5.72	6.16	6.60	7.04	7.48	7.92	8.36	8.80
23	4.60	5.06	5.52	5.98	6.44	6.90	7.36	7.82	8.28	8.74	9.20
24	4.80	5.28	5.76	6.24	6.72	7.20	7.68	8.16	8.64	9.12	9.60
25	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00
26	5.20	5.72	6.24	6.76	7.28	7.80	8.32	8.84	9.36	9.88	10.40
27	5.40	5.94	6.48	7.02	7.56	8.10	8.64	9.18	9.72	10.26	10.80
28	5.60	6.16	6.72	7.28	7.84	8.40	8.96	9.52	10.08	10.64	11.20
29	5.80	6.38	6.96	7.54	8.12	8.70	9.28	9.86	10.44	11.02	11.60
30	6.00	6.60	7.20	7.80	8.40	9.00	9.60	10.20	10.80	11.40	12.00

Annex II. Table for the estimation of the requirement of dilution water for field latex having different metrolac readings and DRC

Metrolac → Reading (g/l)	50	60	70	80	90	100	110	120	130	140	150
% DRC →	20	22	24	26	28	30	32	34	36	38	40
Anticipated % DRC of diluted latex ↓	Quantity of water required for Standardisation of 100 litres of latex (in Litres)										
10.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00
10.50	90.48	109.52	128.57	147.62	166.67	185.71	204.76	223.81	242.86	261.90	280.95
11.00	81.82	100.00	118.18	136.38	154.55	172.73	190.91	209.09	227.27	245.45	263.64
11.50	73.91	91.30	108.70	126.09	143.48	160.87	178.26	195.65	213.04	230.43	247.83
12.00	66.67	83.33	100.00	116.67	133.33	150.00	166.67	183.33	200.00	216.67	233.33
12.50	60.00	76.00	92.00	108.00	124.00	140.00	156.00	172.00	188.00	204.00	220.00
13.00	53.85	69,23	84.62	100.00	115.38	130.77	146.15	161.54	176.92	192.31	207.69
13.50	48.15	62.96	77.78	92.59	107.41	122.22	137.04	151.85	166.67	181.48	196.30
14.00	42.86	57.14	71.43	85.71	100.00	114.29	128.57	142.86	157.14	171.43	185.71
14.50	37.93	51.72	65.52	79.31	93.10	106.90	120.69	134.48	148.28	162.07	175.86
15.00	33.33	46.67	60.00	73.33	86.67	100.00	113.33	126.67	140.00	153.33	166.67
15.50	29.03	41.94	54.84	67.74	80.65	93.55	106.45	119.35	132.26	145.16	158.06
16.00	25.00	37.50	50.00	62.50	75.00	87.50	100.00	112.50	125.00	137.50	150.00
16.50	21.21	33.33	45.45	57.58	69.70	81.82	93.94	106.06	118.18	130.30	142.42
17.00	17.65	29.41	41.18	52.94	64.71	76.47	88.24	100.00	111.76	123.53	135.29
17.50	14.29	25.71	37.14	48.57	60.00	71.43	82.86	94.29	105.71	117.14	128.57
18.00	11.11	22.22	33.33	44.44	55.56	66.67	77.78	88.89	100.00	111.11	122.22
18.50	8.11	18.92	29.73	40.54	51.35	62.16	72.97	83.78	94.59	105.41	116.22
19.00	5.26	15.79	26.32	36.84	47.37	57.89	68.42	78.95	89.47	100.00	110.53
19.50	2.56	12.82	23.08	33.33	43.59	53.85	64.10	74.36	84.62	94.87	105.13
20.00	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00

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