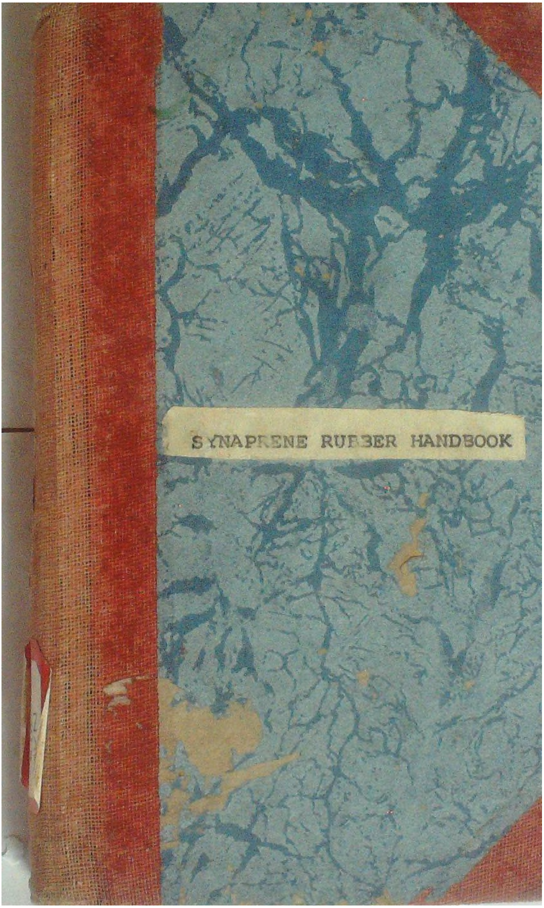

SYNAPRENE RUBBER HANDBOOK

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HAND BOOK

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SYNAPRENE RUBBER
HAND BOOK

Compiled By

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1972

Printed by C. V. Rasal at Miracle Press, Dadar, Bombay 14 and Publi
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FOREWORD

During the Sixtees, when our company's plant for manufacture of Synaprene Rubber came on stream for the first time in 1963, the Indian Rubber Industry has acquired considerable experience and expertise in the use and application of 'Synaprene' Rubbers in a variety of rubber products. The credit for this is in no small measure due to the sustained co-operation extended by Industry to our Rubber Technical Service Laboratory at Bombay and by its encouraging response to the technical assistance rendered by the T. S. Lab. in the form of factory visits, Synaprene Service Letters, Synaprene Formulary Diary and Synaprene Rubber Handbook. Recently, this volume of technical literature was extended in the form of "Project Reports" issued by the Company to assist new entrepreneurs in setting up small and medium scale enterprizes for production of rubber goods and by assisting their training in the Laboratory for developing the required product line or compounds. That the Rubber Industry appreciates these efforts is obvious from the continuing requests for more literature, more visits of our staff and more pressure on training facilities and courses organised by our T. S. Laboratory from year to year.

As the Indian Rubber Industry continues to expand in volume and diversity-and this rate will be considerably accelerated during the seventees-more new knowledge will be essential. The seventees are expected to put Indian Rubber Industry in the front line with the leading industrial nations of the World in terms of consumption of rubber–both natural and synthetic–as well as in the volume and variety of rubber products manufactured and exported from the country. Our Company which has pioneered in the field of Synaprene rubber in India, is continuing to make all efforts not only to expand its overall volume of production of Synaprene rubbers to meet the growing needs of Industry but to also extend the range of these rubbers. These efforts have culminated in the development of new rubber grades, e.g. Synaprene

1513, Synaprene EBR-OE and recently Synaprene S-2000 Latex. Hopefully plans are being made to extend the line still further for production of High Solids Latex for Foam Industry, Nitrile Rubbers and other polymer blends which will help to meet critical gaps in supply position as at present and augment production of rubber goods materially in the days to come.

It is in this context that our Technical Service Laboratory offers this revised and updated "Synaprene Rubber Handbook", to the Industry at this time. It represents a significant effort in pooling all technical information available from the field and in the Laboratory and in developing better compounds for a plethora of rubber products of relevance to the Industry and the Community. The range of products covered in this Handbook has been extended to about 300 numbers. This Handbook is planned to be comprehensive enough and provides adequate data to the Indian rubber moulder, fabricator and producer for all important industrial and consumable rubber goods. This modest effort, it is hoped, will prove rewarding to the Indian Rubber Industry.

Our Laboratory is ever ready to work closely with Rubber Industry on any of its problems and for development of new products. It is with this sense of mission that this "Synaprene Rubber Handbook" is now offered to the Industry and with the abiding hope and trust that it will serve this purpose.

(D. M. Trivedi)
PROJECT MANAGER

Date: 1-5-1972

PREFACE

The growth of our Technical Service Laboratory services and its usefulness to the industry has been significantly extended by the cooperation received from the members of rubber goods manufacturing industry. Also, the positive interest of our Management has played a catalytic role in the growth of our activities. All this has encouraged us to collect, compile and publish this handbook, with the hope that this data will help serve the industry better. This enlarged edition has also been compiled with a specific intent to help the budding technologist not so much from the point of view of a research chemist but rather from the angle of a manufacturer of finished rubber products.

Careful attention has been paid to the extent possible to checking the accuracy of data presented in this book. In actual practice, however, the recipes may possibly vary depending upon the variety of extraneous factors which normally govern rubber compounding in a factory. Therefore, the reproducibility of results that may be achieved with the use of recommended recipes or any other deviations arising out of recommended usage as detailed here can hardly be guaranteed.

The publication of a work of this type has involved assistance from various levels. In particular, my thanks are due to the Project Manager for the valuable guidance and to my colleagues in the Laboratory for their painstaking efforts.

Manu Patel

Synaprene Service (Manu M. Patel)
1st May, 1972 Technical Manager

CONTENTS

CONTENTS

12 Beltings

CONTENTS

CONTENTS

Page

CONTENTS

ABBREVIATIONS FOR PROPERTIES

S. G.	Specific Gravity.
ML_4	Mooney Viscosity @ 100°C.
MS	Mooney Scorch @ 126°C for 5 units rise (unless otherwise specified)
Cure @ 141 °C	Optimum Press-Cure time in Minutes (unless otherwise specified)
T.S.	Tensile Strength, kg/cm^2
E.B.	% Elongation @ Break.
Mod. 100%	Modulus @ 100% Elongation, kg/cm^2
Mod. 300%	Modulus @ 300% Elongation, kg/cm^2
Hardness	Shore A_2 Hardness.
Tear S	Tear Strength – Angle type – Die C, kg/cm
Comp. Set %	Constant deflection @ 25%; I.S. : 3400 (Part X) – 1969, 22 hrs @ 70°C (unless otherwise specified)
T. Set %	Tension Set – I. S. : 3400 (Part XIII)
Flex 1	Ross Flex Machine; Kilo Cycles to 600% cut growth.
Flex 2A	DeMattia Flex Machine; Kilo Cycles to crack growth grade C; I.S. : 3400 (Part VIII)–1967 (K.C. to initiation of pin points.)
Flex 2B	DeMattia Flex Machine; K.C. to 600% cut growth.
Abr. loss	DuPont Abrader Volume loss in cc per hour using I. S. O. type paper C U – 180
Abr. Index	Abrasion Index – I. S. : 3400 (Part III) 1965
Bashore R	Bashore resiliometer, % rebound resilience.
△ T.S.	% Change in Tensile Strength.
△ E.B.	% Change in Elongation at Break.
△ Hardness	Change in Shore A_2 Hardness
△ V	% Change in Volume.
Split Tear	In kgs/2.54 Cms.
V. Cost Rs./L.	Volume cost in Rs. per litre.

ABBREVIATIONS FOR INGREDIENTS

NR	Natural Rubber RMA-1 X
O.E	Oil extended.
WTR	Whole tyre reclaim (Best quality)
NBR (High)	Acrylonitrile Butadiene Rubber-high nitrile content
NBR (Medium)	Acrylonitrile Butadiene rubber Medium nitrile content
NBR (Low)	Acrylonitrile Butadiene rubber-Low nitrile content
CR	Polychloprene rubber (mercaptan modified, medium crystallising)
PVC	Polyvinyl chloride resin.
Mod. P/F resin	Modified phenol formaldehyde resin.
St. acid	Stearic Acid.
H. Ar. Oil	Highly aromatic process oil.
Ar. Oil	Aromatic process oil.
Naph. Oil	Naphthenic process oil.
P. Oil	Paraffinic oil.
P. Jelly	Petroleum jelly.
A. O.	Antioxidant or Antiozonant.
S. P.	Styrenated Phenol.
IPPD	Isopropyl paraphenylene diamine.
PBN & DPPD	Blend of phenyl-B. naphthylamine and Diphenyl paraphenylene diamine.
ETDQ	6-Ethoxy-1, 2-dihydro-2,2,4- trimethylquinoline.
Ketone-amine	Ketone-amine condensate antioxidant.
P. Wax	Paraffin wax
CBS	Cyclohexyl-benzthiazyl sulfenamide.
TBBS	t-Butyl benzthiazyl sulfenamide.
MBS	Morpholinothio benzthiazyl sulfenamide.
DCBS	Dicyclohexyl benzthiazyl sulfenamide.
Hexa	Hexa methylene tetramine.
NDPA	Retarder Nitroso diphenylamine.
TSA	Technical salicylic acid.
DEG	Diethylene glycol.
TEA	Triethanol amine.
DPR-5	Aldehyde amine accelerator.
Cumar	Coumarone Indene Resin (MH)
W. Rosin	Wood Rosin.
DPT	Dinitroso pentamethylene tetramine organic blowing agent

INTRODUCTION

Rubber is one of the most versatile materials of construction known to the world since last century. A multitude of products with specific properties of flexibility, stretch, rebound and abrasion resistance can be made from rubber. Rubber has continued to occupy its position of pride for imparting specific properties to end products among other materials of construction such as steam, cement, plastics etc. The level of consumption of rubber is reckoned with as an index of economic growth of a nation.

Natural rubber was discovered in Brazil in South America about 100 years ago as a milky liquid oozing out of rubber trees. The process of coagulation of the liquid rubber (latex) and the discovery of vulcanisation of rubber made it possible to use it for manufacturing certain products. Over a period, its scarcity was felt and hence afforts were made to augment its supplies by synthetic rubber with properties comparable to those of natural rubber.

The basic concept to chemically synthesize rubber was derived from the knowledge of chemistry and particularly from the molecular structure of natural rubber. The importance of synthetic rubber was first recognised in Germany and Russia during the early 30's. During the first World War Germany was most affected for want of a suitable substitute of natural rubber and determined to ensure that, in the event of another war, the same situation would not recur. During the second

World War, when Western countries were confronted with restricted availability of natural rubber, the planning for commercial production of synthetic rubber gathered momentum.

During the last 25 years, significant quantities of synthetic rubbers have been produced, with the result that whereas, in 1940 the world consumption of synthetic rubber was only 2% of the total consumption of rubber, the corresponding figure for 1970 was 66%. Had it not been for the significant availability of different types of synthetic rubbers, the present stature of the rubber consuming industry might not have been achieved.

The synthetic rubber consumption in the last 25 years has gained such significance that in the U.S.A., the consumption is now 77% of the total. The corresponding figures for other countries are U.K. 59%, Canada 74%, Japan 63%, Germany 64% and Brazil 70%. The percentage of synthetic rubber consumption in 1970 for India was 26.9%.

Apart from the positive role played by synthetic rubber in supplementing the availability of natural rubber, another important aspect of synthetic rubber has been to act as a lever to regulate the prices of natural rubber. There are different types of synthetic rubber now produced the World over, amongst which the important ones are SBR, Polybutadiene, Polyisoprene, Butyl, Polychloroprene, Nitrile, Silicone and Ethylene Propylene. Broadly speaking, the synthetic rubbers are divided into two main categories (a) the general purpose and (b) the special purpose.

As the name implies, the general purpose type of rubbers are the ones which can be used either by themselves or in combination with other rubbers to supplement natural rubber. The special purpose synthetic rubbers impart specific properties to the finished products viz. resistance to oil, resistance to heat or retention of air etc.

Amongst the general purpose rubbers stated above, the most versatile one is the SBR type. This is the oldest synthetic rubber known and has been in commercial production since 1940. This rubber has been so well established the world over that it is called the Work Horse of the rubber industry and today accounts for some 69% of total synthetic rubber production in the World. It was, therefore, more appropriate that India's first synthetic rubber plant was for SBR type synthetic rubber, which has now been in production since May, 1963.

At this stage, a brief review of the Indian scene will not be out of place. India, expect Brazil, is the only country in the world which produces both, natural and synthetic rubber. India has been producing natural rubber since 1902 and has currently about 500,000 acres of land mainly in Kerala, devoted to the production of natural rubber. Until 1956, there was little consumption of synthetic rubber, as India was in fact, surplus in natural rubber. Gradually, the Indian rubber industry started importing small quantities of synthetic rubber and by 1960 was consuming around 11% synthetic rubber. Obviously the know-how for the use of synthetic rubber in the country was limited. Besides, the manufacturers of rubber goods preferred importing natural rubber to synthetic rubber inspite of the fact that the latter was cheaper than the former.

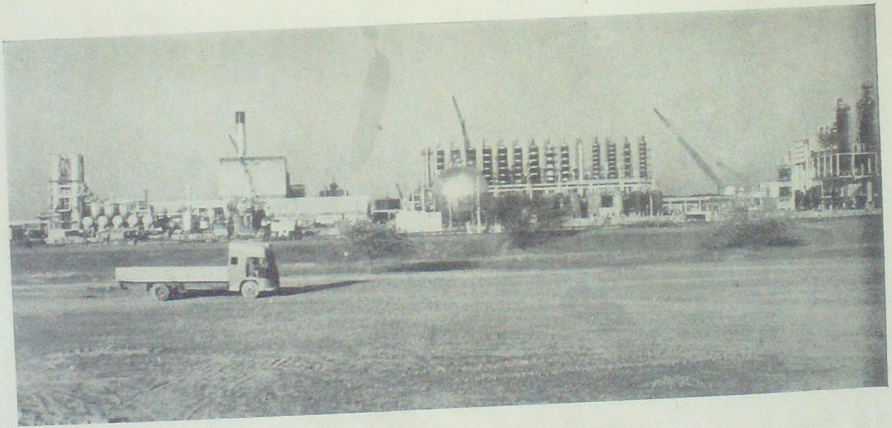
Consideration was given as early as 1957 by the Government of India to plan for domestic production of synthetic rubber in view of the projected increase in demand of rubber. It was felt that if synthetic rubber can be produced locally from indigenous raw materials, the country would be almost self sufficient in rubber.

The foundation stone of the first synthetic rubber plant of India was laid in January 1961, at Bareilly, the epicentre of bouncing sugar industry in the heart of the state of Uttar Pradesh. Designed, engineered and commissioned in a record period of just little over two years, the plant has licensed capacity to produce 30,000 tonnes SBR per annum. The Plant is unique in two ways:

1. The Plant has under one roof units producing styrene and butadiene monomers, the two principal intermediate raw materials for the production of SBR.

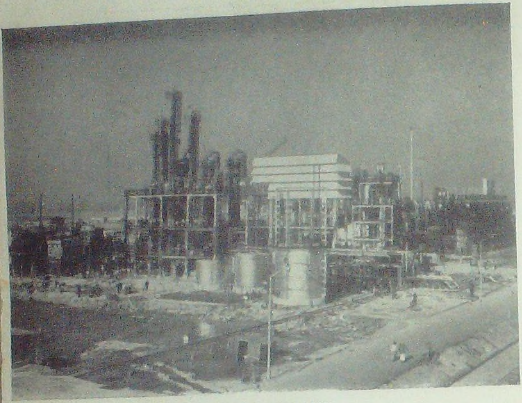
2. The technologies adopted for these plants are the latest and the know-how has been obtained from the most outstanding foreign companies in the world like Chemische Werke Huls, West Germany, for Styrene; Union Carbide, U.S.A., for Butadiene and Firestone Synthetic Rubber and Latex Co., U.S.A., for the Rubber Plant. Any visitor passing by it, cannot but be impressed by its splended massive towers shining throughout the day and be awed by the blazing lights on the gigantic structures illuminating the area during the night. The plant can be rightly described in the words of our late Prime Minister, Jawaharlal Nehru, as a 'Temple of Modern India'.

Since the day of commencement of production, the Plant has produced more than 1,80,000 tonnes of rubber and saved for the country foreign exchange worth Rs. 60 crores. The future of the rubber goods producing industry is well poised for spectacular growth and with it, the future of this plant is associated.

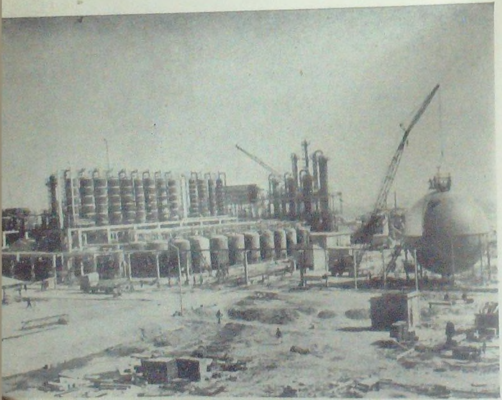


SYNTHETICS & CHEMICALS PLANT – Bareilly

Bird's Eye-view



STYRENE PLANT



BUTADIENE PLANT

MANUFACTURE OF SBR
DETAILS OF PROCESS

(A) MANUFACTURE OF STYRENE MONOMER:

(1) First Ethyl Alcohol is converted to Ethylene by a *dehydration* process:

$C_2H_5OH \longrightarrow C_2H_4 + H_2O$
Ethyl Alcohol — Ethylene

(2) Benzene on alkylation with Ethylene gives Ethylbenzene in the liquid phase process, using aluminium chloride as a catalyst at 95°C.

$C_2H_4 + C_6H_6 \longrightarrow C_6H_5 - C_2H_5$
Ethylene, Benzene — Ethyl-Benzene

(3) Ethyl-benzene is finally dehydrogenated to convert it to Styrene Monomer.

$C_6H_5 - C_2H_5 \longrightarrow C_6H_5 - CH = CH_2 + H_2$
Ethyl-Benzene — Styrene

Styrene Monomer is stabilised by a proper inhibitor to prevent further polymerisation during storage.

(B) MANUFACTURE OF BUTADIENE:

(1) The starting basic raw material is Ethyl Alcohol and it is dehydrogenated to Acetaldehyde.

$C_2H_5OH \longrightarrow CH_3CHO + H_2$
Ethyl Alcohol — (Acetaldehyde)

(2) Acetaldehyde and Ethyl Alcohol are passed over a dehydrating catalyst to produce Butadiene Monomer.

$CH_3CHO + C_2H_5OH \longrightarrow CH_2 = CH\text{—}CH = CH_2 + H_2O$
Acetaldehyde, Ethyl Alcohol — Butadiene

Butadiene Monomer is stored in HORTON sphere under pressure.

(C) POLYMERISATION:

Styrene and butadiene monomers are made to polymerise under strictly controlled conditions of reaction and temperature in a battery of continuous polymerisation reactors using emulsion polymerisation technique. The polymerisation temperature which is very critical during the process, is controlled at 41°F (5°C) for cold rubbers. Some special grades of Synaprenes are made at higher temperatures also.

The conversion of monomers to the copolymer is not carried out to completion for reasons of quality and the polymerisation reaction is short-stopped at a predetermined intermediate stage to obtain the desired properties in the finished Synaprene rubbers. The unreacted monomers are stripped from the latex and recovered for reuse, as recycle streams, in the process after purification.

(D) RUBBER PLANT:

The latex is pumped to the rubber plant where a definite amount of antioxidant or stabiliser is mixed to stabilise the product during the drying process and storage. Here it is coagulated with dilute acid or brine/acid or alum/acid or glue/acid solutions. The resulting slurry is discharged into a holding tank, where the pH is such that most of the soap contained in the rubber is converted into organic acid. The crumbs are then thoroughly washed in a tank to remove the soluble salts, after which the product is dewatered and shredded to facilitate the drying. Shredded crumbs are dried on a conveyor belt at 80-90°C and baled, dusted with talc and packed in loosely laminated polyethylene lined paper-bags.

SYNAPRENE 1514

SYNAPRENE 1514 is a copolymer of Butadiene and Styrene made by cold emulsion polymerisation system using a fatty acid and rosin soap emulsifier. It is a non-staining, non-discoloring type of cold rubber, having high bound styrene and high mooney viscosity. It has very high green strength and tack.

SPECIFICATIONS

Raw Rubber	*Min.*	*Max.*	*Typical*
Volatile Matter, % ..	—	0.75	0.218
Ash, % ..	—	1.50	0.310
Organic Acid, % ..	3.75	7.00	4.835
Soap, % ..	—	0.10	Traces
Non-staining A.O. % ..	1.00	1.75	1.28
Bound Styrene, % ..	38.00	42.00	39.5
Mooney Viscosity, ML4 @ 100°C	65	75	67

Properties of the Compounded Rubber cured at 144.4°C:

	Minutes	*Min.*	*Max.*	*Typical*
Compounded Viscosity, ML4 @ 100°C	—	—	74	71
Ultimate Tensile, kg/cm2	50	218	—	285
Ultimate Elongation, %	50	575	—	650
300% Modulus, kg/cm2	25	24.6	45.7	35
300% Modulus, kg/cm2	50	54.4	88	85
300% Modulus, kg/cm2	100	88	116	105

TEST RECIPE

Polymer		100.0
EPC Carbon black	(NBS)	40.0
Zinc Oxide	(NBS)	5.0
Stearic acid	(NBS)	1.5
Sulphur	(NBS)	2.0
MBTS	(NBS)	2.0

Note: Test Methods are as per ASTM Standards.

APPLICATIONS: Vibration Mountings, Shock Absorbers, Microcellular and Nuclear Solings, Ebonites and other hard rubber products and highly loaded goods.

SYNAPRENE 1712

SYNAPRENE 1712 is a copolymer of Butadiene and Styrene manufactured by a cold emulsion polymerisation system using a fatty acid and rosin soap emulsifier and extended with 37.5 parts of a highly aromatic processing oil.

It is an easy processing staining type, oil-extended, cold rubber. Synaprene 1712 permits significant saving to be made in compounding because of its remarkable physical properties.

SPECIFICATIONS

Raw Rubber	*Min.*	*Max.*	*Typical*
Volatile Matter, % ..	—	0.75	0.29
Ash, % ..	—	1.50	0.24
Organic Acid, % ..	3.90	5.70	4.99
Soap, % ..	—	0.50	Traces
E.T.A. Extract, % ..	30.00	36.60	31.20
Staining A.O., % ..	1.00	—	1.15
Bound Styrene, % ..	21.50	26.50	23.66
Mooney Viscosity, ML4 @ 100°C	48	62	50

Properties of the Compounded Rubber cured at 144.4°C :

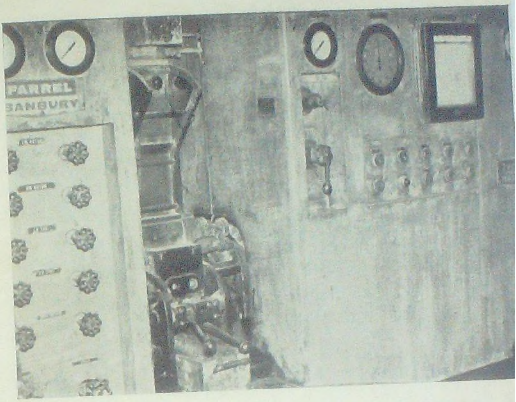
	Minutes	*Min.*	*Max.*	*Typical*
Compounded viscosity, ML4 @ 100°C	—	—	67	56
Ultimate tensile, kg/cm2	50	204	—	232
Ultimate elongation, %	50	600	—	760
300% Modulus, kg/cm2	25	14	28	15
300% Modulus, kg/cm2	50	32	60	41
300% Modulus, kg/cm2	100	53	84	65

TEST RECIPE

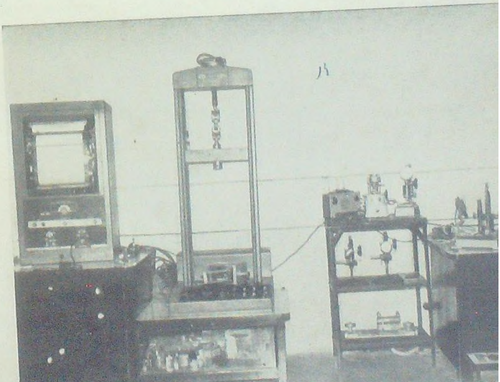
Polymer		100.0
EPC Carbon black	(NBS)	40.0
Zinc Oxide	(NBS)	5.0
Sulphur	(NBS)	2.0
MBTS	(NBS)	2.75

Note: Test Methods are as per ASTM Standard.

APPLICATIONS: Tyre Treads, Camelback, Drive and Conveyor belts, Hoses, Cycle Tyres and tubes and other Mechanical/Moulded and Extruded goods.



PROCESSING SECTION-D Banbury Close-up



PHYSICAL TESTING SECTION – A

SYNAPRENE 1712

SYNAPRENE 1712 is a copolymer of Butadiene and Styrene manufactured by a cold emulsion polymerisation system using a fatty acid and rosin soap emulsifier and extended with 37.5 parts of a highly aromatic processing oil.

It is an easy processing staining type, oil-extended, cold rubber. Synaprene 1712 permits significant saving to be made in compounding because of its remarkable physical properties.

SPECIFICATIONS

Raw Rubber	*Min.*	*Max.*	*Typical*
Volatile Matter, %	—	0.75	0.29
Ash, %	—	1.50	0.24
Organic Acid, %	3.90	5.70	4.99
Soap, %	—	0.50	Traces
E.T.A. Extract, %	30.00	36.60	31.20
Staining A.O., %	1.00	—	1.15
Bound Styrene, %	21.50	26.50	23.66
Mooney Viscosity, ML4 @ 100°C	48	62	50

Properties of the Compounded Rubber cured at 144.4°C :

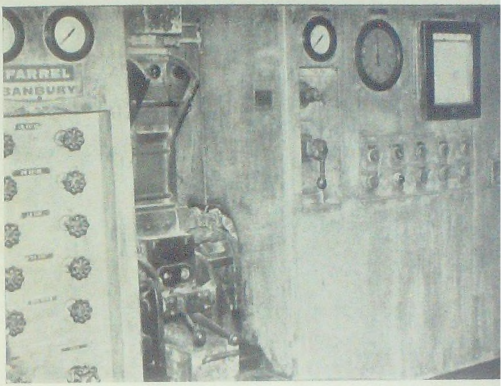
	Minutes	*Min.*	*Max.*	*Typical*
Compounded viscosity, ML4 @ 100°C	—	—	67	56
Ultimate tensile, kg/cm2	50	204	—	232
Ultimate elongation, %	50	600	—	760
300% Modulus, kg/cm2	25	14	28	15
300% Modulus, kg/cm2	50	32	60	41
300% Modulus, kg/cm2	100	53	84	65

TEST RECIPE

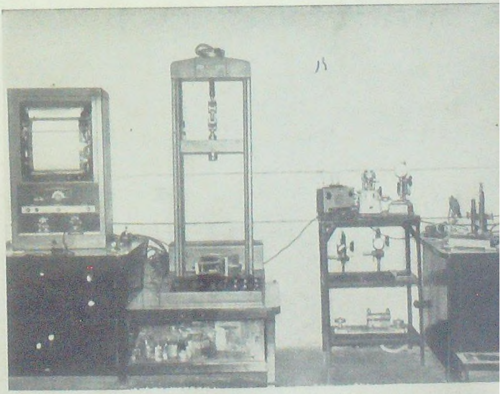
Polymer		100.0
EPC Carbon black	(NBS)	40.0
Zinc Oxide	(NBS)	5.0
Sulphur	(NBS)	2.0
MBTS	(NBS)	2.75

Note: Test Methods are as per ASTM Standard.

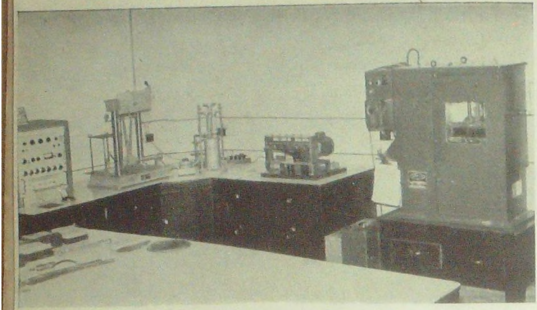
APPLICATIONS: Tyre Treads, Camelback, Drive and Conveyor belts, Hoses, Cycle Tyres and tubes and other Mechanical/Moulded and Extruded goods.



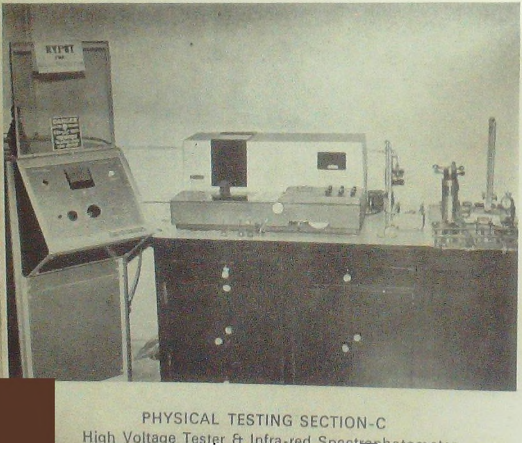
PROCESSING SECTION-D Banbury Close-up



PHYSICAL TESTING SECTION – A



PHYSICAL TESTING SECTION – B



PHYSICAL TESTING SECTION-C
High Voltage Tester & Infra-red Spectrophotometer

SYNAPRENE 1714

SYNAPRENE 1714 is a copolymer of Butadiene and Styrene manufactured by a cold emulsion polymerisation system, using a fatty acid and rosin soap emulsifier and extended with 50 parts of a highly aromatic oil.

It is an easy processing, staining type, oil-extended rubber.

SPECIFICATIONS

Raw Rubber	*Min.*	*Max.*	*Typical*
Volatile Matter, %	—	0.75	0.40
Ash, %	—	1.50	0.22
Organic Acid, %	3.90	5.70	4.75
E. T. A. Extract, %	36.0	42.6	40.8
Soap, %	—	0.50	Traces
Staining A.O., %	1.00	—	1.15
Bound Styrene, %	21.50	25.50	23.65
Mooney Viscosity, ML4 @ 100°C	43	57	45

Properties of the Compounded Rubber cured at 144.4°C :

	Minutes	*Min.*	*Max.*	*Typical*
Compounded Viscosity, ML4 @ 100°C	—	—	67	51
Ultimate Tensile, kg/cm2	50	180	190	205
Ultimate Elongation, %	50	600	600	750
300% Modulus, kg/cm2	25	11	25	18
300% Modulus, kg/cm2	50	25	53	35.15
300% Modulus, kg/cm2	100	42	74	52.7

TEST RECIPE

Polymer		100.0
EPC Carbon black	(NBS)	40.0
Zinc Oxide	(NBS)	5.0
Sulphur	(NBS)	2.0
MBTS	(NBS)	2.75

Note: Test Methods are as per ASTM Standards.

APPLICATIONS: Camelback, Cycle tyres and tubes, Extruded Automotive Rubber Products, Low-cost mechanical goods.

SYNAPRENE 1958

SYNAPRENE 1958 is a self-reinforcing Styrene Butadiene rubber.

Synaprene 1958 is light coloured and is free of staining materials. It is packed in the form of crumbs and bales.

SPECIFICATIONS

Raw Rubber		*Min.*	*Max.*
Volatile Matter, %	..	—	0.75
Ash, %	..	—	0.75
Organic Acid, %	..	4.0	7.00
Soap, %	..	—	0.50
Non-staining A.O., %	..	1.0	2.00

APPLICATIONS: Synaprene 1958 is especially useful for Microcellular solings, Resin soling and leather like products, but it is also valuable in the production of any light coloured rubber products requiring stiffness or hardness, combined with good physical properties, abrasion resistance and moderate flex resistance. It can also be used in the manufacture of toilet seats, steering wheels and other ebonite products.

SYNAPRENE EBR-OE

SYNAPRENE EBR-OE is a homopolymer of Butadiene, manufactured by a cold emulsion polymerization system using a fatty and rosin acid soap emulsifier and extended with 37.5 parts of a highly aromatic oils. It is an easy processing staining type of cold rubber having high abrasion resistance and flex-life.

SPECIFICATIONS

Raw Rubber		*Min.*	*Max.*	*Typical*
Volatile matter, %	..	—	0.75	0.06
Ash, %	..	—	1.50	0.37
Organic acid, %	..	5.0	7.25	5.48
Soap, %	..	—	0.5	Traces
Oil content %	..	24.0	30.6	29.4
Mooney viscosity, ML4 @ 100°C		33	44	40

Properties of the Compounded Rubber cured at 144.4°C :

	Minutes	*Min.*	*Max.*	*Typical*
Compounded viscosity ML4 at 100°C	—	—	48	42
Ultimate Tensile kg/cm2	50	127	—	133
Ultimate Elongation %	50	550	—	575
300% Modulus kg/cm2	25	12.3	33.5	32
300% Modulus kg/cm2	50	24.6	53	51
300% Modulus kg/cm2	100	42	70	68

TEST RECIPE

Polymer	100.0
EPC (NBS)	40.0
ZnO	5.0
Sulphur	2.0
MBTS	2.75

APPLICATIONS: Tyre Treads, Carcass, Camelback and Cycles tyres.

PROCESSING OF SYNAPRENE RUBBERS

Synaprene Rubbers can be processed in a similar way as natural rubber. Machineries required for processing are also similar, however, a few modifications can improve the productivity. Also the processing behaviour of Synaprene rubbers can be improved by minor alterations in the processing techniques.

(1) MASTICATION:

Two roll open mills and internal mixers (Banbury mixer) are used for masticating high molecular weight polymers such as natural rubber and Synaprene rubbers. The rolls of the mill revolve at differential speeds creating friction of the rubber between the nip. For masticating and mixing Synaprene rubbers the preferable friction ratio of rolls at 1:1.15 to 1.3 is adequate. Lower friction ratios on the roll create bagging of Synaprene rubber while higher friction ratios tend to give better breakdown, faster mastication and improved dispersion of fillers in the Synaprene matrix, however, generation of heat is greater with higher friction ratios. Rubber is masticated to reduce the nerve, viscosity and make it more adaptable to subsequent processing.

The main advantage of using Synaprene rubbers is that prolonged mastication is not required. Rubbers band instantly on the mill roll to form a smooth band without development of fish eyes. Synaprene 1513, 1514 band faster than Synaprene 1500, 1502 and 1712.

It is worthwhile noting that when Styrene-Butadiene rubbers were first introduced, the polymer presented many difficulties during mastication and mixing. With the passage of time, the technology of manufacturing and application of SBR has improved. Today, the Synaprenes (SBR) are available which exhibit excellent processing behaviour specially towards mastication and mixing. Indigenous Synaprene rubbers are available to any desired Mooney viscosity ranging from 30 ML4 to 110 ML4. Standard grades such as S-1500, S-1502, and S-1712 are tailor-made to 50 ML4, the viscosity at which the rubber processes on the mill with great ease. A typical effect of masticating natural rubber compared with Synaprene 1502 & 1712 at 55°C is shown as under:—

Time (Minutes)	Synaprene 1502 ML4 100° C	Synaprene 1712 ML4 100°	RMA-1 ML4 100° C
0	52	50	90
6	50.5	38	59
10	49.5	37	52.5
15	47	35	42
30	43	32	31.5

From the above Table, it can be seen that natural rubber degrades much faster compared to Synaprene 1502. A minimum mastication time of 10 minutes is required to breakdown natural rubber to 52.5 ML4 which is the original viscosity of Synaprene 1502. During further mastication, natural rubber keeps on degrading which is not the case with Synaprene rubbers.

(2) PEPTISATION:

Unlike natural rubber, Synaprene rubbers do not need peptisation by chemical agents because the tailored viscosity is good enough for major rubber products. However, for a few applications, where low viscosity is required for the compounded stocks, peptisers like thio β naphthol, zinc salt of pentachlorothio phenol, di-ortho-benzamido diphenyl disulfide, can be used. Peptisation by these chemicals also need higher temperature (about 100-130°C) and after attaining the required plasticity, further break-down of the molecular chains can be arrested by adding sulfur. The normal proportions of sulfur required for vulcanisation are sufficient for the purpose.

However, the latest trend is to start with a polymer having low mooney viscosity like Synaprene 1513. There is another recourse to achieve low compounded viscosity for sponge products by adding high amounts of oil along with small quantity of fine particle carbon black or precipitated silica. This route is very economical also. But in these compounds, the compression modulus values are penalised to a certain extent. The peptisation step can also be carried out in an internal mixer at a controlled temperature.

MIXING EQUIPMENTS

(a) TWO-ROLL OPEN MILL:

During mixing of rubber with reinforcing fillers, high heat is generated due to high stresses and friction involved at the nip of the rolls, where actual mixing takes place. This has led to various changes in the design of the mixing equipment over a period of time. The main modifications being, the drilling of the rolls instead of using a core for efficient cooling by water circulation, use of a special alloy and thin shelled rolls.

When the necessity arises to install a new mixing mill, rolls speeds of 100 and 125 feet per minute should be considered for 22" x 60" mill. Smaller mills should have lower roll speeds for the safety of the operator working on the mill. Following table will serve as a guide to select the right type of mill for Synaprene rubbers.

TABLE: 2

Mill Size in cms.	Batch size Approximate in kgs. Sp. Gr. 1.25	Motor H.P.	Drive Roll RPM
15 x 33	0.68 — 0.90	7.5	30—35
31 x 61	4.54 — 8.2	30— 40	20—30
36 x 76	9.10 —13.6	40— 50	20—25
41 x 107	13.6 —22.6	60— 75	20—25
46 x 122	20.4 —31.8	75—100	20—35
56 x 152	34.1 —56.8	125—150	20—22
71 x 213	79.5 —136	200—250	14—17

(b) INTERNAL MIXER:

The limitations of 2 roll open mill and the pressure on increased production had led to the development of Internal Mixers. An Internal mixer masticates the rubber and mixes the stock rapidly. It is safer and cleaner to work with. During recent years, higher horse power and high pressure machines have come into use for higher productivity, thus resulting in shorter mixing cycles calling for automation in charging and discharging the batches.

Following details on the Banbury mixer are interesting:

TABLE: 3

<table>
<tr><th>Type</th><th>Size Kg. S.G. 1.2</th><th>Rotor RPM</th><th>Motor H. P.</th><th>Gallons of cooling water required.</th></tr>
<tr><td>BR</td><td>1.2</td><td>230|155|116|77</td><td>25|17|12.5|8.5</td><td>—</td></tr>
<tr><td>OOR</td><td>1.8</td><td>125|62.5</td><td>30|15</td><td>—</td></tr>
<tr><td>1A</td><td>11.25</td><td>120|60</td><td>100|50</td><td>25</td></tr>
<tr><td>3A & 3D</td><td>45</td><td>70|35</td><td>300|150</td><td>75</td></tr>
<tr><td>9D</td><td>122</td><td>43|215</td><td>400|200</td><td>150</td></tr>
<tr><td>11 & 11D</td><td>155</td><td>40|20</td><td>600|200</td><td>150</td></tr>
<tr><td>27 & 27D</td><td>340</td><td>32</td><td>1500</td><td>200</td></tr>
</table>

(c) CONTINUOUS MIXER:

Mixing procedure on an open mill and in an internal mixer is a batch process. For continuous mixing operation, CONTINUOUS MIXERS are used. Important features of a continuous mixer, are feed screws, mixing rotors and variable discharge orifice. Method of feeding is very important as the rate of feeding determines the residence of the product in the mixer and the rate of out-put. The rotor speed is variable and it determines the amount of mixing and plasticising that will take place within a given residence time, and the orifice size, the amount of internal pressure developed. Recently, various designs of rotors have been patented and these machines are increasingly getting popular.

(3) MILL MIXING OF SYNAPRENE RUBBERS:

Resinous plasticisers can be incorporated after banding the Synaprene rubbers, accelerators and antioxidants should be mixed after this stage. However, Sulphenamides should be incorporated last in a cool stock. Filler addition can be started at an early stage. In the beginning, reinforcing fillers should be dispersed properly on a tightest possible nip and then different mineral fillers can be added. First half of the reinforcing filler should be mixed without any oil, or plasticiser to get the best dispersion and the physical properties at large. To incorporate very high amount of oil, a paste of oil and fine particle filler should be prepared and added without cutting the stock much. New surface of the stock could be brought by merely changing the nip settings for such a soft compound.

With wide nip in the beginning the band of Synaprene has a tendency to leave the roll as soon as the addition of filler is started. If the filler loading, especially mineral filler loading, is high it is preferable to cut out half the rubber stock from the mill and mix half the filler in the remaining rubber at a thin nip. When the fillers are absorbed, the batch should be cut out, the other half of the rubber loaded on to the mill and mixed with the remaining half of the filler at a thin nip.

Synaprene rubbers absorb fillers very fast at thinner nips and this two step mixing mill actually require less time than when the filler addition is made with all the rubber on the mill. There will also be less of bagging difficulties. Bagging can also be avoided by the help of resinous plasticisers like coumarone-indene resin, aliphatic hydro-carbon resins or modified wood rosin and modified phenolics. For heavily loaded black stocks blown asphalt may be conveniently used to achieve the same. If possible, all resinous plasticisers should be finely powdered before the addition to prevent localised sticking of the rubber stock.

Synaprenes in general tend to go on the fast and cold roll of the mill. Although the mixing is easy, dispersion of fine particle fillers is penalised. Hence, if mixing difficulty arises on the faster roll, this roll should be kept at a higher temperature than the slow roll.

Addition of sulphur should be at the end on a cool mixed stock. However, for Synaprene 1958, sulphur should be incorporated at a very early stage of mixing to get the best dispersion, especially, when sulphur level is high for very hard ebonite products.

Preparation of masterbatches of rubber and reinforcing fillers and if possible also other ingredients, help very much in processing as well as in ultimate physical properties. These masterbatches could be prepared either in an internal mixer or on a mill. When the masterbatch is matured for some time prior to use, due to "wetting" action, the dispersion improves. If the matured masterbatch is further passed through tight nip, the dispersion and ultimately the physicals improve considerably. While blending two or three types of rubbers, the masterbatch of SBR and reinforcing filler would also improve the homogenity of the blends and here also physicals would be excellent.

Synaprene compounds have a tendency to go on to the faster roll., This tendency is pronounced if the friction ratio is high. For better dispersion, the mixing should be carried out on the slow roll with tight nips or by maintaining differential temperature on both the rolls. The complete mixing cycle may not be easy on a slow front roll but at least reinforcing fillers should be dispersed on a slow, front roll.

(4) BANBURY MIXING OF SYNAPRENE RUBBERS:

Synaprene compounds can be mixed easily in Banbury. Volume loading should be same as used with similar natural rubber compounds as the density of these rubbers are almost alike. Premastication of the rubber is unnecessary. Addition of compounding ingredients could be started after breaking down the polymer for about a minute. Filler absorption is quick. For carbon black mixing, especially in Synaprene 1712 dispersion of carbon black is quicker if the stock temperature at the time of addition of carbon black is above 100°C. So it is preferable to cut off cooling water during the initial stages prior to carbon black addition and start it when the stock temperature crosses 100°C. To get clean crumb-free discharge, the dump temperature should be above 140°C.

With the carbon black compounds, dump temperatures should be controlled within 140°C to 160°C to prevent excessive carbon-gel as well as polymer-degradation.

Typical Banbury mixing cycle, along with temperature-rise record and power demand is plotted in figures I and II.

In case of Fig. 1, Carbon black addition was done in one stage. Natural rubber and Synaprene 1712 behave almost alike from the point of view of peak load Kw, total power consumption and temperature rise during mixing, but, Synaprene 1500 demands slightly higher power.

In case of Fig. II, carbon black was incorporated in two stages. Here also, Natural rubber and Synaprene 1712 behave identically. However, Synaprene 1500 exhibits a slightly higher power consumption.

BLENDING SYNAPRENE WITH OTHER POLYMERS

Almost all the major rubber products could be manufactured from Synaprene Rubbers alone. However, blending of Synaprene Rubbers with other rubbers is necessitated to utilise more efficiently the outstanding intrinsic properties of Synaprene Rubber by combining them with the characteristic properties of other rubbers. In certain special cases the property of the other rubber could be tack or green strength. The synergistic effect is easy processing and building-up as obtained when Natural Rubber is blended with Synaprene Rubbers. Or in other cases it may be cost economics where Nitrile or polychloroprene may be blended with Synaprene Rubbers to meet the desired specifications.

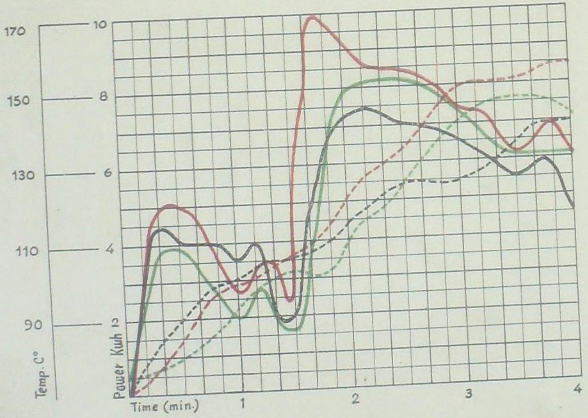
Synaprene Rubbers are compatible with Natural Rubbers, Solution Polybutadiene, Ethylene Propylene Terpolymers (EPDM) and Reclaim Rubber, also with special purpose rubbers like Acrylonitrile-Butadiene Rubbers (NBR), Polychloroprenes (CR), Chlorobutyl and chloro-sulphonated polyethylene rubbers (Hypalon).

For homogenous and thorough blending of two or more polymers, care should be taken that they are mixed together only when their viscosities are nearer. If two polymers with different viscosities are mixed together, the shear force is dissipated in the softer polymer and the high viscosity polymer is not mechanically worked upon. The following points should be considered when Synaprene Rubbers are to be blended with other polymers.

(a) Natural Rubber has high viscosity (ML4 — 80 to 110) compared to that of Synaprene Rubbers (ML4 52 ± 6). Addition of both these rubbers simultaneously to the mill or Banbury will prevent any

Fig. 1 BANBURY : ONE STEP MIXING STUDY

(Tread Type Compound)



Banbury : BR Model

Front Rotor : 116 rpm.

Rear Rotor : 103 rpm

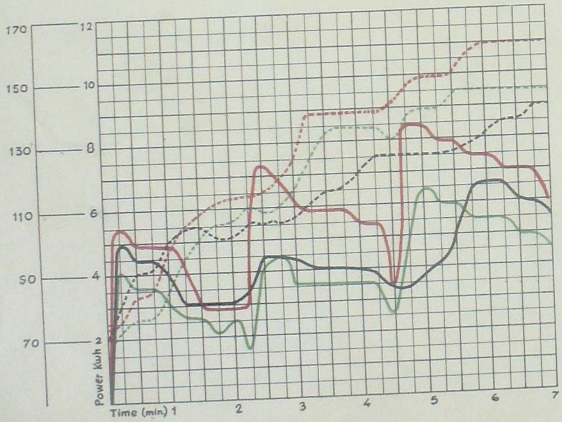
MIXING CYCLE

0′	Polymer
1′	ZnO + A.O.
1 1/2′	HAF + St. acid.
3 1/2′	Sweep
4′	Dump

Temp.	Power	
- - - - - -	▬	NR
- - - - - -	▬	S - 1500
- - - - - -	▬	S - 1712

Fig. 2. BANBURY : TWO STEP MIXING STUDY

(Tread Type Compound)



MIXING CYCLE

0′	Polymer
2′	Half (HAF+St. acid)
4 1/2′	Half (HAF+St. acid)
6′	Sweep
7′	Dump

Temp.	Power	
- - - - - -	▬▬▬	NR
- - - - - -	▬▬▬	S - 1500
- - - - - -	▬▬▬	S - 1712

breakdown of natural rubber. The nerve of the natural rubber would not be killed, leading to high die-swell in extrusion and high shrinkage and rough surface-finish in calendering. For proper results, natural rubber should be premasticated before the addition of Synaprene Rubber to it. The following process should be employed for mill-mixing.

(i) Synaprene Rubber should be passed through tight nip of the mill 2-3 times, without allowing the band to form. The rubber should then be removed from the mill.

(ii) Natural Rubber should be separately broken down to the desired degree. For extrusion or calendering compounds, natural rubber should be broken down till the band surface becomes smooth. For moulded goods compounds, such high degree of mastication may not be often necessary.

(iii) Synaprene rubber should then be added to the natural rubber band slowly, and blended thoroughly.

(b) In mill-mixing, if carbon-black is used in the form of a polymer-carbon black masterbatch, it is preferable using a Synaprene-carbon black masterbatch and adding it to natural rubber rather than using a natural-rubber-carbon black masterbatch and adding it to Synaprene Rubber. Natural rubber-carbon black masterbatch will have a far higher viscosity than Synaprene rubber, hence the addition of such a masterbatch to Synaprene rubber will lead to improper dispersion, poorer processing characteristics and lower physical properties. On the other hand, Synaprene-Carbon black masterbatch will have a viscosity nearer to that of pre-masticated natural rubber.

(c) In blending of the two polymers in Banbury, the usual practice is to add the natural rubber first, followed by Synaprene rubbers. The difficulty in this procedure is that the natural rubber is not sufficiently plasticised to permit the blending of the two rubbers at equal viscosity level, because of the insufficient chamber loading. It is therefore, preferable to use premasticated natural rubber when the two polymers are to be blended.

(d) Whole tyre reclaimed rubber should be added when the blending of other polymers is over. Reclaimed rubber should be homogenised separately and then added.

(e) Acrylonitrile rubber and other synthetic rubbers are also manufactured in similar viscosities nearer to that of Synaprene Rubbers. In such cases both the rubbers should be separately passed through a tight nip of rolls twice without banding and then blended together.

(f) When Synaprene 1958 is to be blended with other Synaprene rubbers, a band of S-1958 should be first formed on the mill to which the other Synaprene rubber (previously passed twice through the tight nip of rolls) should be added slowly and thoroughly blended.

(g) While blending Synaprene 1958 with Natural rubber, Natural rubber should be broken down and removed from the mill. Synaprene 1958 should then be banded on the roll to which natural rubber should be slowly added and thoroughly mixed.

EXTRUSION

Extrusion is the forcing of a plastic material through an orifice (die) so as to obtain the material in continuous lengths of definite shape. In rubber manufacturing, extrusion is used in various operations such as preparation of tyre treads, making of tubes, rubberising bead wire and straining. At times it is also called forcing and tubing.

Synaprene rubbers are basically ideal for extrusion because their extrusion characteristics are solely a function of the compounding ingredients used unlike natural rubber, where it depends to a great extent on the care with which the compounds are processed earlier and hence all the characteristics like extrusion rate, die-swell, product-finish vary from batch to batch. The consistency of extrusion characteristics of the batches is very important for continuous bulk production, when the dimensions of the products are to be controlled within the limits. Because of their scorch resistance and the latitude of using reworked material, Synaprene compounds require far less rigorous controls in the extrusion department than natural rubber compounds.

With proper loading of the correct type of fillers, it is possible to achieve as good extrusion rates with SBR compounds as with natural rubber compounds. It is possible to increase the screw speeds upto 50 to 60 rpm and get a higher rate of extrusion with Synaprene Rubbers. But for NR compounds, the screw-speeds should be 30 to 40 rpm only as the viscosity decreases rapidly at higher speeds.

High structure blacks like FEF and reinforcing china clays impart excellent extrusion characteristics.

The normal rubber extruder is adequate for extrusion of Synaprene stocks however a high speed extruder should be preferred for higher productivity. Typical extruder should be preferred for higher productivity. Typical extruder specifications for SBR are:

Length—diameter of scroll: 4:1 or 5.5:1
Pitch of Scroll = Diameter of Scroll
Depth of Flight = 1/6 Diameter of Scroll.

The scroll should be internally bored to facilitate water-cooling. The jacket should be water-cooled and the feed-hopper should preferably have both steam and water connections for heating and cooling.

To avoid scorching difficulties and to get good production rates, barrel clearance should be low, 0.01-0.02 mm per centimeter diameter of scroll is adequate.

The scroll may be single, double or triple flighted. It can also be with constant pitch, variable pitch or variable depth. When pitch or depth is varied compression ratio should be about 1.5 to 1.

The width of the hopper should uncover atleast two flights of the screw and the undercut in the hopper should be 2.5-3 cms. from the centre.

The land (straight region) of the dies for Synaprene compounds should preferably be greater than that in the dies for natural rubber compounds.

For extrusion of Synaprene compounds die-temperatures are required to be higher by about 10°C to 15°C than those for natural rubber compounds of corresponding viscosity. Die temperatures of 100°C to 110°C have been found to give good surface-finish to the extrudate. Barrel and scroll should be kept cold, except in the case of stiff compounds, (e.g. high hardness carbon black loaded compounds) a slightly warm barrel gives faster extrusions. In many cases a warm feed zone will improve feed-rate.

In the case of very soft compounds, e.g. sponge compounds with high oil loadings, difficulty may arise because of "biting off" of the feeding strip and sticking of the compound to the screw. In such cases dusting of the strip with whiting would help to overcome the trouble.

In case of polymer blends, proper blending is very essential for getting low die swell and better extrudates, hence very light dusting or at times just passing soap water is sufficient to avoid any likely sticking of the extrudates during storage or cure.

Extrudates of Synaprene compounds have less tendency to sag and deform during storage or cure.

Die-swell of Synaprene 1500 with 50 HAF is 40%, while that of Synaprene 1712 is 55%. For NR with 50 HAF, the die-swell depends upon compounded mooney viscosity, e.g. for 60 mooney viscosity (ML4 @ 100°C the die-swell is 40%).

It is important to note that the efficiency of an extruder will go down if the screw and liner clearance will increase due to continuous operations in the factory. Hence the materials of constructions are very important in designing screws and liners of the extruders.

Screws are made of steel alloy forging, heat-treated to a machinable hardness and hard chrome-plated, the flight lands should be either surface hardened to approximately Rockwell 'C' 50-55 or covered with a special hard alloy consisting of 12-17% tungsten, 30-35% chromium, 2.25 to 2.27% carbon and balance cobalt. It has a Brinnel hardness of approximately 600. Likewise, the liners of the barrel should be corrosion resistant in the form of a detachable sleeve for relining. The alloy used for lining material is 38% Nickel, 38% cobalt, 8% chrome, 6% molebdenum, 4% silicon and 3% boron.

Note: 70 Rockwell "C" = 800 Brinel Hardness

TABLE: 4

DATA ON TYPICAL RUBBER EXTRUDERS

Extruder Size (cms.)	Motor H. P.	Max. Screw speed RPM	Aver. cap. kgs./hr. @ 50 RPM	Aver. die area sq. cm.	Max die area sq. cm.
3.81	3—5	80	23—27	2.90	4.84
6.35	5—8	80	91—114	4.84	9.67
8.89	20—30	90	204—227	9.67	19.35
11.43	30—45	90	386—408	17.70	35.48
15.24	50—75	78	749—772	32.26	64.51
20.32	100—150	78	1634—1679	61.94	129
25.40	125—175	78	3042—3087	103	226
30.48	150—200	58	4313—4404	155	323

CALENDERING

Calendering is a process which is used for continuously sheeting or plying up rubber compound, and frictioning or coating fabric with rubber compound by a machine equipped with three or more heavy, internally, heated or cooled rolls revolving in opposite directions.

Calendering compounds of Synaprene Rubbers is more or less similar to that of Natural Rubber. However, a few typical characteristics of Synaprene Rubbers should not be overlooked. The calendering characteristics of Synaprene Rubbers depend more on the compounding ingredients as the componded viscosity does not lower down much on working and reworking on the mill and also its thermo-plastic behaviour in processing is different from that of Natural Rubber.

By proper compounding, controlled calendering characteristics can be easily obtained with Synaprene Rubbers. Proper loading with proper type of fillers is the key. In many cases, the products required are coloured and hence above 200 phr loading of soft-clay with 5-7 phr of Cumar resin would give compounds with excellent calendering characteristics.

Synaprene compounds have a tendency to go on to the cooler roll. In a three-roll calender, therefore, the middle roll temperature should be atleast 5°C lower than the top roll temperature. Synaprene compounds require slightly higher calender-roll temperature to give a good surface finish.

Temperature control need not be very critical as in case of Natural Rubber Compounds. Lower thermo-plasticity of Synaprene rubbers permits the compounds to be calendered over a wider temperature range than corresponding natural rubber compounds.

Reworked material can be freely used along with the fresh stock since Synaprene Rubber compounds do not lose much in viscosity or green strength so readily as natural rubber compounds.

The most common calender is a three roll calender, whose centre roll is fixed and driven. The top and bottom rolls move up and down, for the adjustment of nips and they are driven by gears with the help of the centre roll. Gears are also provided for operating the rolls at uneven speed for "frictioning" operation.

Apart from three roll calender, 4 roll calenders of vertical, 'L' type, inverted 'L', 'Z', and inclined 'Z' type are also used.

For sheeting operation or skim-coating, the defect such as "crow's feet" can be eliminated by temperature control. While the "blistering" can be got rid of by the use of "pricker" bars attached to the calender. The sizes of rolls, speed and power data are given below:—

TABLE: 5

DATA ON TYPICAL RUBBER CALENDERS

Size D x L (cms.)	H. P.	Weight (Tons.)	Mtrs./min.
20 x 62	10	7	4.50
25 x 75	15	9	5.61
30 x 92	25	14	6.75
35 x 105	30	17.5	7.95
40 x 120	40	22	9.00

Synaprene compounds can also be spread with the help of a spreading machine. The rubber compound is soaked in a petroleum rubber solvent and the swollen mass is homogenised by a solution mixer, having typical blades and the "dough" is prepared. Low Mooney Synaprene rubbers do offer advantages in preparing a dough faster, thus saving power and giving increased productivity.

METHODS OF VULCANIZATION

Vulcanization is a process in which rubber, through a change in its chemical structure (e.g. cross-linking), is converted to a condition in which the elastic properties are conferred or reestablished or improved or extended over a greater range of temperatures. In some cases, the process is carried to a point where the substance becomes rigid.

Vulcanization is carried out by different methods, depending upon the type and size of the products.

The recent developments lead to classify the process of vulcanization in two categories:

(1) *Batch Vulcanization.*
(2) *Continuous Vulcanization.*

Again "Batch Vulcanization" comprises of:

(a) Press Moulding
    Compression type
    Transfer type
    Injection type
    Blow Moulding.
(b) Open steam curing.
(c) Dry Heat curing.
(d) Hot Water vulcanization.

and "Continuous Vulcanization" (C.V.) comprises of:

(a) Rotocures.
(b) C.V. in steam tubes.
(c) Liquid curing method (L.C.M.)
(d) Fluidised Bed Method (Ballotini).
(e) Ultra High frequency micro-wave method (UHF)

In our country, straight compression types of moulds are generally used because of low cost and ease of fabrication. Transfer moulding offers various advantages over compression type, when the articles are complicated in shape and the dimensional tolerances are critical. Also, the trimming labour is minimised. Techniques in designing of transfer mould can bring about "Trimless Moulding".

Injection moulding is getting more and more popular abroad for mass production of items like soles and heels, washers, rings, brake cylinder cups, and injection bottle-caps, because of the fast rate of production, (Cure cycles are as low as $1\frac{1}{2}$ minutes), consistent quality with the added advantage that the products do not require trimming. Capital Investment is however, very high. Blow moulding is used for the manufacture of hollow articles like play-balls and rubber bulbs.

Moulds: The thermal co-efficient of expansion of rubber is far higher than that of the mould metal. To compensate for the shrinkage occuring in the rubber article on cooling from cure temperature, mould cavity dimensions have to be made fractionally larger than the required dimensions of the rubber product. This "shrinkage allowance" is of similar order for equivalent natural rubber and Synaprene compounds, therefore, the same mould can be used for both.

The shrinkage allowance to be considered is approximately calculated by the formula:

Shrinkage allowance % = T x A x K, where,

T : difference between curing temperature and room temperature in °C.

A : difference between coefficient of expansion per °C for the metal and Synaprene rubber.
$= 205 \times 10^{-6}$ for steel moulds.
$= 194 \times 10^{-6}$ for aluminium moulds.

K : Volume percentage of rubber and acetone soluble substances present in the compound.

For moderately loaded compounds, generally, the shrinkage allowance can be taken at 1.5% as a first approximation.

Where critical tolerances are required, it is advisable to determine the exact shrinkage allowance for the compound in any mould prior to the fabrication of the new mould.

Ordinary mild steel is used for making the mould, because of ease of machining and low cost, and it is quite satisfactory for Synaprene compounds. To lengthen the service life of moulds, the parts which are subject to heavy wear, viz. the dowel pins should be made from high carbon steel and should preferably be heat hardened. Bushing of similar nature should be used for lining of the dowel holes.

Though Synaprene rubbers do not corrode the mould, sulfur in the compound and some chemical byproducts of vulcanization have a sort of etching action on the mould surface and thus deteriorate the original surface of the mould.

Negligence in the maintenance of moulds can result in high rejection rates and disruption in production schedule.

Cleaning frequency varies from type of compounds. Hence programming and cleaning of moulds is essential.

Where high lustre on the finished product is essential, hard chromeplating (0.008-0.040 mm) should be used. For normal uses, unplated moulds can be occasionally cleansed by soft grit-blasting, using rice husk or almond shell powder as grit. Aluminium moulds can be cleansed by chromic acid treatment.

Press: Hand presses or hydraulic presses can be used for the purpose of vulcanization. The platen pressures required are independent of the type of elastomer used, but are dependent only on the nature of compound and the mould used. For practical purposes, 45 kg/cm^2 platen pressure can be considered as adequate. To avoid distortion of platens, ram diameter should be 75% or above of the average platen dimensions. Platens should be minimum 5 cm. thick and press should have an adequately thick bolster and head. For precision mouldings the head bolster and platens should not deflect to more than 0.05 mm per cm. of platen dimension under full pressure.

Approximate steam consumption of the press can be taken 1 kg/Hr per 900 sq. cm. of exposed surface of the platen e.g.

Press Dimensions	*Approximate steam Consumption kgs/hr.*
60 cm x 60 cm — 2 daylights: (4 exposed surfaces)	16 to 20
45 cm x 45 cm — 4 daylight: (8 exposed surfaces)	18 to 22.50

For trouble-free production, good temperature controls, good steam distribution inside platens by proper core design and efficient drainage of condensate are a must.

For electrically heated presses controlled by thermostats, a wattage of 2 KW per 1000 sq. cm. of platen area should be provided to avoid wide temperature fluctuations.

Moulding Temperature: Synaprene Rubbers are resistant to reversion at high temperatures. High temperatures upto 175°C can be used for curing of Synaprene compounds without the fear of development of tacky surfaces. The cure cycles can thus be reduced for higher output.

Optimum Cure Time: This will depend on the important property, desired in the product. The tensile and tear strength and flex resistance are optimum at "90% cure" for most of the Synaprene compounds. However, Abrasion resistance, resilience and compression set are optimum at "95% cure." Hence a cure has to be selected from the end property required, otherwise a compromise has to be arrived at. Modulus remains marching but a step next to sudden rise in 300% Modulus could be very conveniently taken as an optimum cure time.

Optimum cure time can also be obtained by means of instruments like Oscillating Disk Rheometers, Viscurometer, Cepar, Vulkameter, Wallace Shawbury Curometer and other instruments.

Temperature—Coefficient of Vulcanization : The value of temperature coefficient depends on the energy of activation for the vulcanization system used rather than on the compounding ingredients. Synaprene rubber and natural rubber compounds having similar curing systems have similar energies of activation and thus have similar temperature-coefficients of vulcanization. The temperature-coefficient varies slightly with temperature, but for all practical purposes, it is 2 per 10°C in the normal temperature ranges used for moulding. With a temperature coefficient of 2 per 10°C the cure time will be halved for every 10°C rise in temperature or will be doubled for every 10°C lowering in temperature.

Allowance in cure time for thickness of the rubber article : Optimum cure time for a compound is generally obtained from the physical test data obtained on thin laboratory specimen. Rubber products are not as thin as the specimen. Rubber is a non-conductor of heat, hence in thick rubber articles, certain time elapses before the rubber mass attains the curing temperature. A practical rule of thumb is to increase cure time by five minutes (@ 138°C) for every $\frac{1}{2}$" thickness of the article beyond first $\frac{1}{2}$".

Backrinding: Rubber being a nonconductor of heat, it takes time for the heat to soak through into the central region. If the compound cures on the outside before the central region gets heated and expands thermally, high pressures are developed in the central region. This pressure may overcome the moulding pressure and get released by tearing of the vulcanized outer skin and throwing out the excess spew at the parting line. If this does not occur during cure, at the time of opening the press, the pressure gets released at the parting line and the article has torn edges at the parting line. This defect is known as backrinding. Preheating the stock by dielectric heating or otherwise will overcome this defect. Mould design is also important. Use of semi- positive moulds instead of straight compression type moulds will overcome the difficulty to some extent. Use of delayed action accelerators and better conducting fillers like zinc oxide and lower temperatures of cure are advantageous. Synaprene rubbers are better conductors of heat and the severity of backrinding is generally less.

Mould Lubricants : Synaprene rubber compounds do not have any greater tendency to stick to the moulds than corresponding natural rubber compounds and same type of mould release agents, more sparingly used will be found adequate. Silicone emulsions, polyethylene glycols and soap solutions are commonly used.

Finishing : Synaprene rubber goods can be deflashed and finished in the normal way by hand trimming with the help of scissors and knives or by punching. The recent methods developed to reduce the labour cost of trimming are the deflashing methods with the help of solid carbon dioxide. The rubber articles are chilled almost to their brittle temperatures. The chilled articles are tumbled together or sprayed with a mild abrasive (wheel abrader). The thin flash breaks away cleanly without any injury to the article proper.

Halogenation: When a completely tack-free surface with a silky finish (very low coefficient of friction) is desired, treatment of the goods for one minute in the following solution has been found satisfactory.

Sodium hypochlorite solution	(5.25%)	3 vols.
Conc. Hydrochloric acid	(37%)	0.5 vols.
Water		100 vols.

Halogenation also increases the strength of the bond if the vulcanized article is to be bonded afterwards with metal.

COMPOUNDING OF SYNAPRENE RUBBERS

Compounding is still an art, however it is becoming more scientific. Advanced countries are using computers as the tool for compounding. In the good old days, the technology was not advanced, but today, the course of vulcanization is known sufficiently well and there are various methods and tools by which the compounder can design a compound with great accuracy without struggling on trials and errors.

Gum rubber vulcanizates of natural rubber have very high tensile, elongation, resilience but low modulus, hardness and tear strength, abrasion and flex resistance. At the same time gum rubber vulcanizates of Synaprene Rubbers exhibit low physical properties. But when NR and Synaprene 1500 are compounded at optimum level of reinforcing fillers, they are almost alike in most of the physical properties.

The designing of the compound can be broadly classified as follows :—

(1) Selection of Rubber or Blends.

(2) Filler System
   - Reinforcing and/or diluent fillers
   - Plasticizers and Softeners.

(3) Curing System
   - Activators
   - Accelerators
   - Main Curing Agent

(4) Protective System.
   - Anti-Ageing Auxillaries

While designing the compounds with Synaprene Rubbers, one should know the individual characteristic of each grade of Synaprene Rubber and the effect of various other compounding ingredients on them. The basic properties of NR and SBR are tabulated below :—

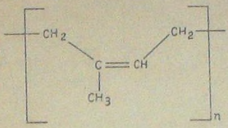
TABLE: 6

COMPARISON OF BASIC PROPERTIES OF NR & SBR

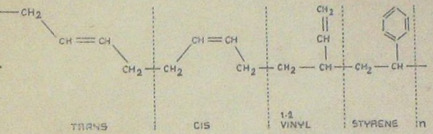
Nature/property	NR	SBR
Composition	Hydrocarbon	Hydrocarbon
Micro-Structure:		
Cis content %	97.8	12.3
Trans content %	—	71.8
Vinyl content %	—	15.8

FORMULA - EMPIRICAL

NR:



SBR:



Effect of stretching	Crystallizes. This property contributes to high gum strength.	Does not crystallize. Thus low gum strength.
Glass Transition Temp. °C	— 72 to — 75	— 59 to — 64
Specific Gravity	0 93	0.9326 (24% Bound styrene)
Specific Heat (raw) cal/gm. °C	0.449	0.453
Thermal conductivity cal./sec. cm. °C	(3.1×10^{-4})	(3.9×10^{-4})
Coefficient of cubic expansion.	$670 \times 10^{-6}/°C$	$660 \times 10^{-6}/°C$
Heat of combustion Cal/g.	10,700	13,498

Refractive Index.	1.52	1.5148 to 1.5611
Cohesive energy (by solution method) Density Cal/cm^3	68.06	68.72
Mooney Viscosity	Varies from 65 to 120	35 to 100 tailored to requirements.
Conductivity Ohms/cm.	2-57 x 10^{-17}	3-99 x 10^{-15}
Dielectric strength, volts/mil	600 to 800	500 to 700
Dielectric constant, 500 cycles/sec.	2.68	2.83
Power factor, 500 cycles/sec.	0.0062	0.0029
Resistance to animal & Vegetable Oils.	Poor	Good to Poor
Petroleum & Lubricating oils	Poor	Poor
Aliphatic & Aromatic solvents.	Poor	Poor
Acid resistance	Good	Good
Corrosion	Non-corrosive	Non-corrosive
Moisture resistance	Fair	Good
Ageing	Fair to Good	Fair to Good

It can be observed from above that SBR very much resembles NR in most properties. The molecular irregularity and large pendant groups in SBR prevent aligning of molecules to give crystals on stretch thus it differs with NR. The lack of crystallization capacity gives lower green strength and also lower gum tensiles. To overcome this type of behaviour of SBR, incorporation of fine reinforcing fillers is necessary. Good tear resistance is also an outcome of molecular rearrangement and crystallinity on stretch. To overcome this lack in SBR again calls for the necessity of fine active fillers which help in improving tear strength.

Currently eight grades of Synaprene rubbers are available to the Indian Rubber Industry and their individual characteristics are summarised below from the angle of compounding and processing :

SYNAPRENE 1500 : Synaprene 1500 has a Emulsifier system based on Rosin Acid which results in (a) slightly slower cures compared to Synaprene 1502 & (b) better tack. S-1500 gives highest physicals amongst the Synaprene family, thus it is recommended for premium quality products. It is a stabilized with PBNA (staining A.O.) and imparts best storage stability and heat ageing in finished products.

SYNAPRENE 1502: Instead of Rosin Acid, in Synaprene 1502 the emulsifier system consists of Rosin acid/Fatty acid combination. Thus it has better cure rate but lesser tack compared to S-1500. Stabilized with non-staining A.O. and hence can be used for compounding of brightly coloured and white rubber products.

SYNAPRENE 1513-X : It is a low mooney viscosity rubber with high bound styrene. It has very good low green shinkage properties together with high green strength. Due to its low mooney viscosity, it allows easy blending of various other rubbers and the mixing time as well as the power consumption are low.

SYNAPRENE 1514 : It is high mooney viscosity rubber, having high bound styrene content. It bands instantaneously on the mixing mill and due to its higher green strength it can be extended with higher amounts of fillers and plasticizers to make it more economical. It has excellent damping characteristics and this property can be exploited for vibration and shock isolation in the engineering rubber products.

SYNAPRENE 1712 : This grade is an oil-extended staining type of rubber, having 37.5 phr of highly aromatic oil. The oil makes this grade not only economical and easy processing but gives reasonably high physical properties.

SYNAPRENE 1714 : This grade is also an oil-extended staining type of rubber, having 50 phr of a highly aromatic oil. It is more economical than S-1712 but the physical properties are slightly lower.

SYNAPRENE 1958 : Synaprene 1958 is a self-reinforcing rubber. It is possible to achieve higher hardness and excellent abrasion resistance at a low density with this grade. Leather like products and high impact coloured ebonites can be developed from S-1958.

SYNAPRENE EBR-OE-X: This is an easy processing staining type of cold polymerized homopolymer of butadiene, extended by 37.5 parts of highly aromatic oil. Synaprene EBR-OE gives vulcanizates having high abrasion resistance and flex. Resilience of EBR-OE is better than S-1712. It is used in blends with natural rubber.

At times, for specific properties like building tack or high resilience, Natural rubber has to be blended with Synaprene rubbers. At the same time, for reduction in cost, reclaimed rubber can also be blended with Synaprene rubbers. Synaprene rubbers can also be easily blended with special purpose synthetic rubbers, to reduce not only the cost but to improve processing characteristics, yet maintaining adequate physical properties.

FILLER SYSTEM : Synaprene rubbers need reinforcing fillers to develop good physical properties. Reinforcing carbon blacks like furnace blacks are perferred in compounding of synaprene rubbers and various grades are freely available in our country. However, the reinforcing non-black fillers of consistent quality are yet to make the scene in the market. Next to furnace blacks, hydrated silica, precipitated calcium and aluminium silicates, natural hard clays are good reinforcing fillers. Although precipitated and activated calcium carbonates are moderate in reinforcement, the processing characteristics imparted are very good.

Synaprene 1500 with as little as 30 phr of HAF black develops the tensile strength of 233 kg/cm^2 and 600% elongation at break. There is always an optimum level of reinforcement by a fine particle filler and then a gradual drop in physicals occur; e.g. HAF shows optimum for Tensile and Tear Strength at 50 phr, but other properties may show a different optimum peak.

Between black and non-black fillers, one would always choose black if permissible as it shows the highest reinforcement. ISAF, HAF, FEF activate cure but do not cause as much scorch hazards in Synaprene Rubbers as they do in NR. With highly reactive furnace blacks and fast curing system, nitroso diphenyl amine (NDPA) type of retarder is effective for Synaprene rubbers.

White carbon or hydrated silica is next to fine furnace black, but it does not impart very high modulus at a lower loading in Synaprene. Hydrated Silica, precipitated silicates and natural hard clays retard the cure at a high loading and to balance the cure time, activators like Polyethylene Glycols and Triethanolamine should be used. Usually, for every 20 to 30 phr of the retarding filler, 1 phr of diethylene glycol is adequate.

However, the upper limit for Glycols should be 4 phr. But triethanolamine should be used very judiciously, as it is very scorchy even when used at 1 phr level.

RESINOUS PLASTICISERS: Presence of process aids like Coumarone Indene Resins, aliphatic resins, modified rosins, modified phenolics, are absolutely essential to improve dispersion of mineral fillers. Thereby considerable improvement in physical properties can be achieved. At the same time, building tack and other processing characteristics are also improved. Softeners like petroleum oils are very useful in Synaprene compounding not only from the view point of cost but for improved processing. Synaprene rubbers can take-up very high dosage of aromatic and naphthenic oils unlike natural rubber. High amounts of mineral fillers dry up Synaprene very fast, hence suitable processing oils should be incorporated in large amounts while compounding Synaprene rubbers.

OIL PLASTICISERS : Petroleum oils are the most common softners. They range from highly aromatic to aromatic, naphthenic and paraffinic oils. All these are available in various grades of viscosities and staining power.

When softners are used in small dosages, merely to improve processing the aromatic oils are suitable. But for very high dosage of softners along with high amounts of carbon black or mineral fillers naphthenic oils are preferred from the view-point of compatibility and age resistance. Paraffinic oils and petroleum jelly should be used only when internal lubrication and high gloss are required. Aromatic oils give staining and discoloring type of vulcanizates but naphthenic and paraffinic oils give non-staining and non-discoloring vulcanizates.

Oil characteristics depend upon its place of origin and the nature of refining. Most oils sold under trade names are a mixture of two or more oils. Such mixing are necessitated to ensure a consistant product. Low molecular weight oils should be avoided in such blends, which may lead to vaporization at processing temperatures.

Though factors like specific gravity, volatility, refractive index, pour point, flash point, Anilene point may indicate the type of oil being either aromatic, naphthenic or paraffinic the preferred classification of oil types may be based on 'Viscosity gravity constant' (VGC), which is also recognised by ASTM, and is given by the formula.

$$\text{VGC} = \frac{G - 0.24 - 0.022 \log_{10} (V_2 - 35.5)}{0.755}$$

Where; G = Specific gravity at 60°F
V_2 = Saybolt viscosity at 210°F

CLASSIFICATION OF OIL TYPES BY "VGC"

Oil Description	*Range*
Paraffinic	0.791—0.820
Relatively naphthenic	0.821—0.850
Naphthenic	0.851—0.900
Relatively aromatic	0.901—0.950
Aromatic	0.951—1.000
Highly aromatic	Over 1.001

The classifications are approximate and refers to the predominant component in the oil.

A typical analysis of range of rubber processing oils is given in the appendix.

TABLE: 7

GENERAL PROPERTIES OF RUBBER PROCESSING OILS

	Aromatic oil	*Naphthenic oil*	*Paraffinic oil*
*Compatibility	Excellent	Good	Good
	Excellent	Excellent	Good
	Excellent	Good to Excellent	Poor
	Fair	Fair	Good
	Good	Fair	Poor
Processing†	Excellent	Good	Poor
Volatility (200°C)	None	A little	None
Staining	Poor	Good to Excellent	Excellent
Discoloring	Poor	None to a little	None
Curing rate	Fast	Medium	Slow
Rebound	Fair	Good	Excellent
Tensile strength	Good	Good	Good
Mod. 300%	Good	Good	Good
Hardness	Good	Good	Good
Heat build-up	High	Medium	Low
Low temp. property	Fair	Good	Excellent

* Compatibility with Rubbers like Natural Rubber, SBR, Polychloroprene, Butyl, Nitrile.

† For general purpose rubbers like SBR & NR.

N.B.: Details of effects of various fillers and plasticisers on various grades of Synaprene rubbers are given on pages 70-76.

ACTIVATORS: Zinc oxide and stearic acid are normal activators. In comparison with natural rubber, the proportions of zinc oxide and stearic acid may be taken lower. 3 to 3.5 phr of zinc oxide is sufficient in normal compounding. 1 to 1.5 phr of stearic acid is sufficient for Synaprene 1500. But for other grades even one phr of stearic acid also gives adequate activating effect. When Synaprenes are compounded with only hydrated silica (more than 30 phr) there is no need of zinc oxide.

ACCELERATORS : All the accelerators used in NR are useful for Synaprene rubbers and mode of action is similar. Synaprene Rubbers need higher dosage compared to NR — for the same rate of vulcanization, e.g. in tread-type compounds, the levels of Sulphenamides like CBS or TBBS for NR and Synaprene should be :

		CBS or TBBS
NR	....	0.5 to 0.6
S—1500	....	1.0 to 1.2

For soft vulcanizates, Thiazoles and Sulphenamides are used as primary accelerators, while Guanidines, Thiurams and Dithiocarbamates are used as secondary accelerators or boosters. For low modulus, Guanidines should be preferred, as Thiurams and Dithiocarbamates always give higher modulus stocks when used as boosters and the cures are "Peaky". Only Guanidines have synergistic effect on Thiazoles and Sulphenamides while other boosters have only additive effect.

SBR ebonites are accelerated by Aldehyde-amines or Guanidines.

Soft vulcanizates :	1 to 1.5 phr thiazoles with or without 0.25 to 0.5 phr Guanidine or Thiuram.
Ebonites :	1 to 2 phr Guanidine or Aldehyde Amine or DPR-5.

Guanidines alone produce brown spots but when used as a booster, it shows little effect. The table summarises the action of different accelerators in Synaprene 1500.

TABLE: 8

Accelerators in SBR 1500

SBR 1500	100	St. Acid	2
HAF	50	Accelerator	1.1
Process Oil	10	Sulphur	1.8
ZnO	4		

	MS @ 138°C	Cure Mins. @ 153°C	TS kg./cm^2	E.B.	Mod. 300% kg/cm^2	Shore 'A'
TMTD	3.5	15	211	310	210	64
TMTM	9.5	15	200	335	180	63
F	10	30	211	485	113	56
MBTS	13	45	209	660	70	53
MBT	11	60	200	610	70	51
CBS	20.0	45	253	505	127	57
TBBS	20.5	45	257	485	137	57
MBS	25	45	250	495	124	56
DCBS	20.9	60	253	530	124	56
DPG	40	90	208	590	81	56

As observed above, Sulphenamides are the best for balanced rate of cure, safety and physicals. Thiurams alone with normal sulphur are too scorchy. Dithiocarbamates are not shown, but they will also behave in the same way. Though DPG gives very good processing safety, it gives very low physicals and very long cures are essential. Thiurams produce high modulus with low elongations.

Other effects of Accelerators:

(1) Thiazoles and sulphenamide impart bitter taste to the vulcanizate.
(2) Guanidines produce slightly brown stain.
(3) Longer storage of certain sulphenamides is not recommended.
(4) Aldehyde-Amines are staining and discoloring type.
(5) Thiurams and Dithiocarbamates give "peaky" cure.
(6) Only TMTD based SBR vulcanisates tend to show bloom and also impart odour. Small additions of sulphur and 50% replacement of TMTD by TETD takes care of this problem.
(7) Dithiocarbamate accelrators are non-toxic.

CURING AGENTS :

(a) *Sulphur Cure* :

Sulphur is a versatile curing agent for Synaprene Rubbers. But in comparison with NR, the dosages required are lower :

	Synaprenes	*NR*
Soft Vulcanisates	1.5 to 2.0 phr	2.0 — 2.5 phr
Ebonites	35 to 40 phr	40 — 50 phr

(b) *Non-Elemental and Low Sulphur Cure* :

Sulphur bearing accelerators like TMTD, TETD, and TMTM and sulphur donor ingredient like 4-4', dithiobismorpholine (Sulfasan R) can vulcanise Synaprene Rubbers with low sulphur or without sulphur.

Rate and state of cure can be controlled by varying Sulphur, TMTD and Sulphur donor levels. Such systems offer vulcanisates with excellent heat resistance and fatigue life with low compression set. TMTD cure system with or without sulphur tends to show blooming of curatives or reaction products of curatives after some time. In such cases, substitution of a part of TMTD by TETD helps to minimise this problem. Very high dosage of MBTS or CBS (5 phr) with low sulphur (0.33 to 0.5 phr) also impart excellent heat-resistance and flex characteristics to Synaprene Rubbers.

(c) *Sulphurless Cure* :

Synaprene Rubbers can be also vulcanised by the following systems :

(1) Dicumyl Peroxide (3.75 phr with or without low sulphur)
(2) Benzo-quinone dioxime (2 phr with or without Pb_3O_4)
(3) m-Dinitrosobenzene (3 phr with PbO — 5 phr)
(4) 1, 3 — Dimercaptobenzene (2 phr)
(5) Dimethylol-phenol Resins (with Halogen donors) This system is less practical because it imparts very high modulus.
(6) Phenylene bismalemide.
(7) Radiation Cure (Gamma rays).

PROTECTIVE AGENTS: Unsaturated rubbers even after cross-linking, are susceptible to attacks of Oxygen, Ozone, Heat, Sunlight and Metallic ions of Fe, Mn, and Cu which catalyse the attack of Oxygen. Synaprene Rubbers are more susceptible to Fe poisoning rather than Cu and Mn. Also Synaprene Rubbers relatively show better heat ageing than NR. However, for ozone resistance, it has to be protected more efficiently.

The following Table shows relative effects of various antioxidants and antiozonants on Synaprene Rubbers:

TABLE: 9

GENERAL EFFECTS OF ANTIOXIDANTS ON SBR.

A. O. Class	Natural Ageing	Heat Ageing	Flexing	Staining	Copper & Manganese
1. Phenyl-naphthyl amines.	C	C	C	F	F
2. Diphenylamine Derivatives.	C-D	C	B-E	D-F	F
3. Para-phenylene diamine derivatives.	C	C	C-F	E-F	B-C
4. Ketone-Amine Condensates.	C	A-C	B-F	E-F	F
5. Aldehyde-Amine Condensates.	C-E	C	E-F	D-F	F
6. Substituted Phenols	D-E	D-F	E-F	A-E	F
7. Phenolic Sulphides	C-D	D	E-F	B-D	D-E
8. Phenol-Aldehyde Condensates.	C	C	C-E	B-C	D-E

A = Excellent; B = Very Good; C = Good; D =Moderate; E = Fair; F = Poor.

Very limited types of antioxidants and antiozonants are available at present.

They are:

1. Phenyl-B-Naphthyl amine.
2. Styrenated Phenols.
3. IPPD (N-Isopropyl-N'-Phenyl-p-phenylene-diamine)
4. ETDQ (6-ethoxy, 2,2,4-trimethyl, 1-2, dihydro-quinoline)
5. Ketone-Amine Condensate Product.
6. Mixture of DPPD and PBN.
7. DMBPPD N-(1,3-dimethylbutyl)-N'-phenyl-p phenylene diamine.

Paraffin Wax and other micro-waxes bloom to the surface and form a thin film. This film is a good weather protector under static condition. It is also used along with antiozonants for more effectiveness. The dosage of antiozonant should be larger for S-1712 compared to S-1500 or S-1502.

AUXILIARIES: Apart from the above normal compounding ingredients, there are various other materials which are used at times in compounding, to have special properties.

(1) RETARDERS: Synaprene rubbers seldom need a retarder for normal compounding, however, for very large-size extrusions and fast curing systems, 0.25 to 1 phr of retarders like N-nitroso diphenylamine, surface treated phthalic anhydride, benzoic acid and salicylic acid are used to safeguard against scorch-hazard and for good mould flow.

(2) BLOWING AGENTS: Inorganic blowing agent like baking soda ($NaHCO_3$) can be used for open-cell sponge products. 12 to 15 phr can give reasonably good open-cell structure. Cell-structure can also be improved by dispersing the blowing

agent in heavy fatty oils like linseed oil or by controlled dosages of stearic acid. Organic blowing agent like Dinitroso Pentamethylene tetramine is used for non-communicating cell-structure (micro-cells). Here also the decomposition temperature of a highly alkaline blowing agent should be lowered by controlled dosages of stearic acid.

(3) PIGMENTS: For white and pastel shades of colours, anatase grade of Titanium Dioxide is the best covering pigment. For other colours, organic pigments, free of ionic Fe, Cu and Mn, should be used. Abrasives like pumice powder, and asbestos, extenders like Brown and White Factice, rayon flock can be used with Synaprene Rubbers to impart special properties.

(4) FLAME RETARDANTS:

Of the many service properties that rubber has to comply with one of them is fire retardancy, whenever required. Two types of burnings are encountered. One is in the flame and the other outside the flame. All elastomers ignite in the flame, but the degree and speed of combustion is dependant on the polymer type and the compounding ingredients used. The polymers which extinguish out side the flame are halogen bearing types, while general purpose rubber hydrocarbons continue to burn outside the flame.

The following points are useful in compounding rubbers to be flame retardant:

(1) Halogen bearing elastomers like Polychloroprene, Chlorosulphonated polyethylene and Fluoro carbons are inherently fire retarding.

(2) Flame proofing of rubbers is almost similar to that of polyolefins like polyethylene, polypropylene, poly-

styrene and other synthetic polymers with all carbon back-bones.

(3) Due consideration must be given to the reactivity of fire retarding compounding materials as unlike plastics rubbers are milled, vulcanized and hence are to be protected against oxidation.

(4) Halogen bearing stable organic compounds are the back bone of a fire retardant system. Bromine halides though more expensive are more effective as a fire retardant than chlorine halides.

(5) Antimony compounds by themselves are ineffective as fire retardants but when used along with halogen compounds they exhibit a synergistic effect in flame propagation control. Similar is the case with phosphorous compounds.

(6) Diene rubbers like poly-butadiene or SBR may be made fire retardant by incorporating hexachlorocyclopentadiene.

(7) Al $(OH)_3$ seems to help reduce flammability when chlorine is also present, besides it is much more inexpensive than Sb_4O_6.
A 10 phr. of Al $(OH)_3$ is considered adequate.

(8) Hydrated silica and preferably pyrogenic silica also aid in fire retardancy.

(9) Zinc borate is also used as a flame supressant.

A typical formulation is given below.

FLAME-RESISTANT SYNAPRENE COMPOUND

Synaprene 1502	100.0
Calcium Silicate	20.0
Hard clay	80.0
Aluminium Hydroxide	20.0
Chlorinated Paraffin	30.0

Process oil N	5.0
Antimony Trioxide	12.0
White factice	15.0
ZnO	4.0
Zinc Borate	5.0
Stearic acid	1.0
TEA	0.5
A. O. Styrenated phenol	1.0
A. O. ETDQ	1.0
CBS	1.2
DPG	0.2
TMTD	0.2
Sulfur	1.8

Cure: 20' at 152°C (2 mm. thick)

SALIENT FEATURES FOR COMPOUNDING

The science of developing a formulation depends on following factors:

(1) The rubber must possess the basic properties that will enable it to serve the intended purpose.

(2) The properties of compounding ingredients should be carefully considered.

(3) The compound should be capable of easy processing in the factory, with a minimum waste and rejected articles.

(4) The cost of materials, power and labour should be minimum.

(5) The technical specifications laid down for end products should be carefully considered during designing.

This interplay between different factors often puts production formulas in a delicate state of balance. As the newer raw materials keep on pouring in, the technologist has to alter formulations from time to time as there is nothing like a "Master Formula". In developing specific components from Synaprene Rubbers, the following principles should be observed.

(1) Use 3 to 4 parts zinc oxide.

(2) Use 1.5 to 2.5 parts of stearic acid.

(3) Use 1.5 to 2.5 parts of polyethylene glycols and/or triethanol amine in case of rubbers reinforced with hydrated silica and silicates.

(4) Use atleast 5 to 7 parts of process oil for good dispersion of fillers. Higher quantity of petroleum oil can be used provided proper balance is maintained with filler proportions.

(5) USE ATLEAST 20 TO 30 PARTS OF CARBON BLACK OR SILICA. MUCH HIGHER PROPORTIONS CAN BE ADDED DEPENDING UPON THE ULTIMATE PROPERTIES REQUIRED.

(6) Use a combination of antioxidant and antiozonant ranging from 1 to 3 parts.

(7) Use of 1 to 1.5 parts of Sulphenamides is quite common.

(8) Rubber auxiliaries can be used to improve or modify the properties of the compound and the vulcanizate.

(9) Use of high black, high oil is preferable to dilution with mineral fillers to reduce compound cost.

Finally, while selecting oil-extended rubber (S-1712) for further compounding, it must be treated like a straight polymer (S-1500). A comparative data for a typical tread type recipe is shown below where some adjustment in the curatives is done:

Synaprene 1500	100	—
Synaprene 1712	—	100
ISAF Black	45	45
Zinc Oxide	3	3
Stearic Acid	1.5	1.5
Antioxidant PBN	1	1
Pine Tar	7	2
CBS	1	0.7
DPG	0.20	0.14
Sulphur	1.75	1.23

Using these recipes, it is found that oil extended rubbers can be fairly compared with straight rubbers from the point of view of performance coupled with substantial cost reduction.

BASIC STUDY ON SYNAPRENE RUBBERS

Study of basic properties of Synaprene Rubbers is very vital. It is through such studies that the materials used can be successfully applied to develop end products. In the foregoing tables, the effect of compounding Synaprene rubbers and its impact on physical properties are shown. After each study the conclusions are drawn for easy understanding.

Various blends of rubbers are studied, and effect of black and non-black fillers and effect of extenders are also reflected in experiments conducted, mainly focussed on Synaprene Rubbers.

TABLE: 10

SYNAPRENE 1500 & NR BLENDS

Basic Recipe

Polymer	100.0	Zinc Oxide	4.0
HAF	24.0	Stearic acid	1.0
ISAF	20.0	A.O. Ketone-amine	1.0
Ar. Oil	5.0	A.O. IPPD	1.0
		Retarder NDPA	0.5

	(1)	(2)	(3)	(4)	(5)	(6)
RMA-1X	100	90	85	80	70	—
S-1500	—	10	15	20	30	100
TBBS	0.5	0.5	0.5	0.6	0.65	1
Sulphur	2.5	2.5	2.5	2.4	2.35	2
ML4 @ 100°C	58	60	58	56	51	56
MS @ 143°C.	7'37"	8'25"	8'30"	9'	9'12"	11'50"
Cure @ 141°C for 35 min.						
T.S.	305	308	307	297	280	265
E.B.	575	550	550	550	525	500
Mod. 100%	22.7	25	24	24	24	22
Mod. 300%	130	146.5	136	137	129	134.0
Hardness	61	64	64	65	65	65
Tear S	93	75	73	74	53	41
Bashore R.	45	45	45	44	44	40
Flex 2A	33	69	260	132	131	300
Flex 2B	29	31	28	25	16.3	8.4
Abr. Loss	2.0	2.62	1.61	1.54	0.94	0.60
Heat Gen. Avg. Max. temp developed during 100 KC run*	92°C to 93°C	94°C to 96°C	89°C to 96°C	96°C to 98°C	96°C to 102°C	120°C to 122°C

* Fatigue bend testing machine-model DPG I
VEB Thuringar Industriwerk Rauenstein
Radius of Curvature of Bend: 45 mm.

COMMENTS:

(1) Upto 15 parts of S-1500, there has been no alteration in curatives which is adequate in maintaining major properties, as there is no significant change.

(2) Although, the optimum cure-timings are same, scorch-hazard is getting minimum with increase in Synaprene 1500.

(3) Tear strength and resilience drops with increased S-1500 level.

(4) Crack-growth resistance improves with increase in S-1500.

(5) Abrasion resistance improves with increased S-1500 level.

(6) The heat generation data indicates possibility of using 40 parts S-1500 in truck tread depending upon tread design and shoulder thickness. The overloading increases heat generation and hence for very large sizes 30 phr level could be an upper limit in such applications.

TABLE: 11

SYNAPRENE 1712 & RMA BLENDS

Polymer	100	MBTS	
FEF	50		0.6/100 RMA
China Clay	25		1.2/100 S-1712
Naph. Oil	10	TMTD	
Zinc Oxide	3		0.2/100 S-1712
St. Acid	2	Sulfur	
PBN	1		2.5/100 RMA
			1.75/100 S-1712

S-1712	100*	80	60	40	20	—
RMA	—	20	40	60	80	100

ML4 @ 100°C	47.5	41	36.5	35.5	39.7	55.5
MS @ 126°C mins.	14	11.5	10.5	10	9	9
RC (cure Index) mins.	2.86	1.91	1.65	1.38	1.53	1.93
Cure @ 141°C 20 mins. for test slabs. (2mm)						
Vulcanizate properties						
T.S.	133	144	156	167	166	174
E.B.	540	490	480	450	430	430
Mod. 300%	91	99	101	107	103	92
Hardness	64	65	68	69	69	65
Tear S.	35	37	36	35	47	54
Comp. set.	29	25	27	26	31	35
Bashore R.	28	31	31	36	38	42
Abrasion R. Rating (NR-100)	112	137	138	124	113	100
Ageing 168 *hrs.* @ 70°C						
△T.S. %	—17	—17	—15	—16	—10	—16
△E.B. %	—44	—37	—31	—25	—22	—22
△ Hardness	+ 6	+ 5	+ 4	+ 3	+ 3	+ 5
Ageing 168 *hrs.* @ 100°C						
△T.S. %	—25	—30	—37	—50	—55	—76
△E.B. %	—58	—72	—69	—64	—64	—73
△ Hardness	+10	+ 9	+ 7	+ 3	+ 3	+ 2

* The blends were made by mixing compounds of the two rubbers and hence ML4 values of the blends are lower.

Notes and Observations:

(1) Note the change in curing system; it is on a prorata basis.

(2) The oil level is kept constant even when S-1712 is oil extended rubber.

(3) The most important point is that with blending of as much as 40% S-1712 and RMA, there is no significant decrease in T.S., E.B. Tear.

(4) Significant improvement in resistance to abrasion and improvement of compression set is noted.

(5) Resilience drop is small with increase in S-1712.

(6) Ageing is not practically affected upto 40 phr S-1712 at 70°C. But as the proportion of S-1712 increases, the severe ageing shows improvements.

(7) Scorch safety increases with S-1712, which is a processing advantage.

(8) Thus it could be concluded that S-1712: RMA blends are very useful in compounding for balanced properties and prices.

SYNAPRENE AND RECLAIM BLENDS

Blending with reclaim has the apparent draw for compounding a product for cheapness. This is not the whole truth. Reclaims help in processing, ageing, and compounding for ebonites. Also compounding Synaprene with reclaim can give low Sp. gr. compound. The blends give faster curing compounds.

TABLE: 12

SYNAPRENE 1500 & WTR BLENDS

Polymer	100	CBS	1.0/100 S-1500
HAF	25		0.4/200 WTR
ZnO	4	Sulphur	2.0/100 S-1500
St. Acid	1.5		2.5/200 WTR

	1	2	3	4	5	6
S-1500	100	80	66	50	33	—
WTR	—	40	66	100	132	200
S.G.	1.07	1.09	1.11	1.13	1.15	1.18
ML4 @ 100°C	60	58	57	56	54	45
MS @ 126°C	24'	10'9"	12'30"	12'	11'36"	10'
Cure time in min. @ 141°C	30	30	25	25	20	20
T.S.	226	169	142	110	98	58
E.B.	550	550	435	375	325	225
Mod. 300%	71	75	82	85	85	—
Hardness	55	57	58	58	60	62
Tear S.	39	37	37	30	24	16
Abr. Loss	1.14	2.22	2.64	3.71	4.70	8.65
Flex 2A	127	65	23	18.5	9	< 1
Flex 2B	52	48	42	26	2	< 1
After air-oven ageing @ 70°C for 72 hrs.						
△ T. S.	— 12.3	— 16.4	— 8.2	+ 2.6	+ 6.3	+ 12.8
△ E.B.	—18.3	—21.2	—18	—19.8	—12	—15.8
△ Mod. 100%	+ 3.8	+ 10.3	+ 21.8	+ 25	+24.6	+ 31.1
△ Mod. 300%	+ 28.4	+ 30.7	+ 32.2	+ 34.8	+ 18.7	—
△ Hardness	+ 3	+ 3	+ 3	+ 4	+ 5	+ 5

COMMENTS:

(1) Compounded mooney viscosity drops as reclaimed rubber increases. In other words, the mould-flow characteristics of the compounds are inferior with higher reclaim.

(2) As the reclaim percentage increases the scorch-hazard increases.

(3) However the rate of cure of S-1500 could be increased by controlled increase in WTR.

(4) Tensile strength, elongation, modulus and tear strength increase with increase in S-1500.

(5) Abrasion resistance decreases with the increase in WTR and more over, it falls very rapidly from 66 phr WTR and onwards.

(6) Good flex resistance is also maintained upto 40 phr WTR and onwards it is quite poor both for development of crack growth and cut-growth resistance.

TABLE: 13

SYNAPRENE EBR-OE & NR BLENDS

(Emulsion Polybutadiene-OE)

Polymer	Varied	P. Wax	1
HAF	50	A.O. IPPD	1
Zinc Oxide	4	CBS	0.4 to 1 (varied)
Stearic Acid	2	Sulphur	2.5 to 1.8 (varied)
A.O. PBN	1		

EBR-OE	Nil	20	40	60	80	100
RMA 1 X	100	80	60	40	20	Nil
CBS	0.4	0.52	0.64	0.76	0.88	1.0
Sulphur	2.5	2.36	2.22	2.08	1.94	1.8
ML4 @ 100°C	56	56	58	57	56	57
MS @ 126°C mins.	11	13	16	19	20	23
Green tack in gms (Wallace)	Above 1000	Above 1000	Above 1000	1000	900	570
Cure @ 141°C in mins.	30	30	30	45	45	45

T.S.	299	285	260	215	189	181
E.B.	550	560	500	450	400	400
Mod. 300%	145	145	149	144	134	127
Hardness	63	63	63	63	61	61
Tear S.	88	81	65	44	41	41
Flex 2A	65	73	85	165	203	584
DuPont abrader Wear rating (RMA-100)	100	130	139	160	200	220
Bashore R	43	41	37	37	37	37

After air ageing at 100°C *for* 72 *hrs.*

△ T.S.	—60	—56	—47	—40	—22	—18
△ E.B.	—35	—51	—47	—47	—44	—35
△Hardness	+ 2	+ 3	+ 5	+ 5	+ 7	+ 7
Bashore R	41	40	38	38	38	38

COMMENTS:

(1) EBR-OE upto 60 phr maintains the high tack of NR unlike other oil-extended polymers.

(2) Although T.S. and Tear drop with increase in EBR-OE crack growth resistance is fairly improved.

(3) Although resilience drops slightly with increase in EBR-OE, the abrasion resistance improves at a very fast rate.

(4) With increase in EBR-OE, the ageing improves.

TABLE: 14

SYNAPRENE EBR-OE & S-1712 BLENDS

Polymer	100	St. Acid	2
HAF	50	A.O. PBN	1
Ar. Oil	3	A.O. IPPD	1
Zinc Oxide	4	P. Wax	1

CBS	Varied	Sulphur	1.3
DPG	Varied		

EBR-OE	100	70	30	—
S-1712	—	30	70	100
CBS	0.7	0.64	0.56	0.5
DPG	0.2	0.17	0.13	0.1
ML4	47	49	46	48
Cure 144°C (mins.)	45	45	45	45
T.S.	152	172	192	210
E.B.	550	575	600	600
Mod. 300%	67	73	75	76
Hardness	55	55	56	57
Tear S	35	36	41	44
Bashore R	33	32	30	29
DuPont abrader wear Rating S-1712=100	185	148	127	100
Flex 2A	307	276	252	231

COMMENT:

(1) Due to increase in S-1712, the T.S. and Tear improves however % E.B. 300% Modulus and Hardness remain unaffected.

(2) Due to increase in EBR-OE the resilience of S-1712 improves steadily.

(3) Abrasion resistance of EBR-OE is superior to S-1712 and in blends it improves the abrasion resistance of S-1712 gradually.

(4) Crack growth resistance of EBR-OE is outstanding and gradual increase in EBR-OE improves the same property of S-1712.

TRIPLE BLENDS OF SYNAPRENE-NR-RECLAIM

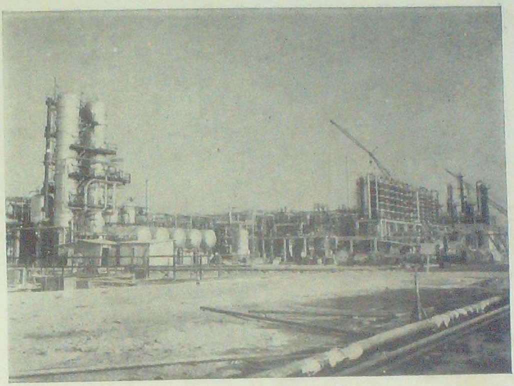
Compounds on triple blends are common for carcass compounds of truck, passenger, scooter and motor cycle tyres and also giant tyres. Such blends are also used for cycle treads, hoses, mechanical moulded goods, soles and heels, commercial ebonites and other rubber products.

After studying the basic characteristics of blends like S-1500/EBC 3X/WTR and S-1712/EBC 3X/WTR with 25 phr HAF, one can easily design the specific compounds like cycle treads and hoses by further dilution with mineral fillers and plasticisers, taking care on levels of curatives.

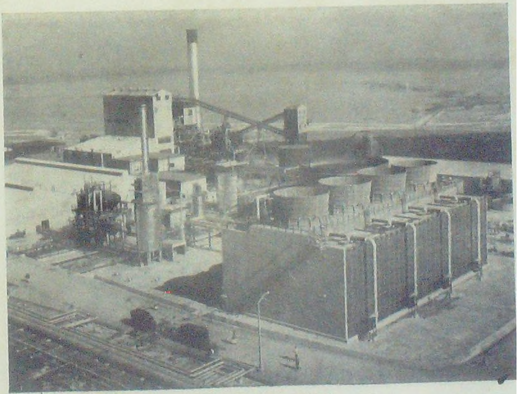
TABLE: 15

SYNAPRENE 1500-EBC-3X-WTR STUDY

	1	2	3	4	5
S-1500	40	60	40	50	40
EBC 3X	40	20	30	20	20
WTR	40	40	60	60	80
HAF	25	25	25	25	25
Zinc Oxide	4	4	4	4	4
Stearic acid	1.5	1.5	1.5	1.5	1.5
PBN	1	1	1	1	1
CBS	0.64	0.76	0.64	0.64	0.64
Sulphur	2.28	2.18	2.27	2.27	2.26
S.G.	1.13	1.13	1.15	1.15	1.17
ML4 @ 100°C	39	42	36	37	36
MS @ 126°C	15'37"	15'30"	14'51"	13'30"	13'30"
Cure @ 141°C (min)	20	20	20	20	20
T.S.	201	188	166	164	141
E.B.	575	575	500	500	475

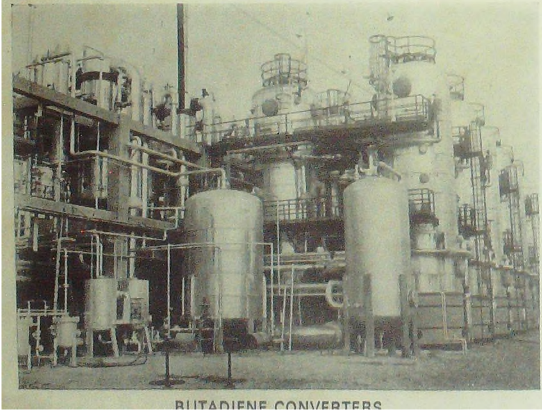


LATEX PLANT (Left side)



UTILITY SECTION

CONTROL ROOM – Styrene Plant



BUTADIENE CONVERTERS

Mod. 100%	16.9	17	19	20	20.6
Mod. 300%	68	68	69	69	70
Hardness	59	60	61	62	63
Tear S	41	38.5	36.1	36	30
Abr. loss	2.92	2.82	4.25	3.65	4.35
Flex 2A	130	162	69	69.8	44
Flex 2B	98	57	44	44	24

COMMENTS:

(1) Due to increase in reclaim, physical properties like T.S., E.B., Tear S, drop gradually but flex and abrasion resistance drop at a faster rate. At 40 phr reclaim rubber level most of the physical properties are reasonably high.

TABLE: 16

SYNAPRENE 1712-EBC 3X-WTR STUDY

	1	2	3	4	5
S-1712	40	60	40	50	40
EBC 3X	40	20	30	20	20
WTR	40	40	60	60	80
HAF	25	25	25	25	25
ZnO	4	4	4	4	4
St. acid	1.5	1.5	1.5	1.5	1.5
PBN	1	1	1	1	1
CBS	0.56	0.64	0.56	0.62	0.56
Sulphur	2.20	2.06	2.19	2.09	2.18
S.G.	1.13	1.13	1.15	1.15	1.17
ML4 @ 100°C	36	36	34	33	33
MS @ 126°C	14'44"	16'30"	14'30"	14'30"	14'
Cure @ 141°C (mins.)	30	30	25	25	25
T.S.	181	164	147	150	121
E.B.	575	560	525	550	475

Mod. 100%	20	17.7	20.7	18	20.8
Mod. 300%	73	64	74	66.5	68.6
Hardness	59	60	61	62	63
Tear S.	37	35	34.2	31.6	30
Abr. loss	3.84	3.38	4.82	4.45	5.1
Flex 2A	79.1	300	150	37.3	56
Flex 2B	48	32.25	31.5	29.6	22

COMMENTS:

(1) Such triple blends could be utilised where low cost compounds with low physical properties are considered adequate.

TABLE: 17

EFFECT OF INCREASED LOADING OF HAF IN SYNAPRENE 1500

Base Recipe

S-1500	100	St. acid	3
HAF	Varied	A.O. Ketone-amine	1
AR. Oil	8	CBS	1.2
ZnO	3	Sulphur	2

Comp. No.	(1)	(2)	(3)	(4)	(5)	(6)
HAF	20	30	40	50	60	70
Cure @ 141°C, 35' for all compounds.						
T.S.	169	233	252	250	239	232
E.B.	600	625	650	550	500	450
Mod. 300%	38	67	118	122	148	162
Hardness	46	50	56	62	67	71
Tear S.	40	45	55	57	61	58
Abr. Loss	2.2	1.7	1.4	0.6	0.3	0.34
Flex 2A	> 200	>200	> 200	>200	> 200	> 200
Flex 2B	42	60	61	60	38	13

COMMENTS:

(1) Upto 50 phr HAF, tensile strength goes on increasing but it drops on higher loading.

(2) Ultimate elongation increases upto 40 phr HAF but it drops on higher loadings.

(3) 300% Modulus increases and abrasion resistance progressively improves on increased loading of HAF upto 70 phr HAF.

TABLE: 18

EFFECT OF NAPHTHENIC OIL IN SYNAPRENE 1500

Base Recipe

S-1500	100	St. acid	2.5
HAF	60	MBT	0.75
Naph. Oil	Varied	MBTS	0.75
ZnO	4	PBN	1
		Sulphur	2.0

Compd. No.	1	2	3	4	5
Naph. Oil	—	10	20	30	40
ML4 @ 100°C	76	60	51	41	32
Cure @ 152°C (mins.)	15	15	15	15	15
T.S.	234	221	192	171	152
E.B.	300	340	410	550	600
Mod. 300%	234	198	148	120	92
Hardness	72	67	62	59	52
Tear S	38	41	37	35	28

COMMENTS:

(1) Mooney viscosity drops progressively by increasing the level of oil.

(2) Tensile strength, modulus, hardness and tear strength drop slowly due to increase in oil level.

(3) Ultimate elongation increases with increased loading of oil.

(4) Economical compounds are possible with oil loading.

TABLE: 19

EFFECT OF NAPHTHENIC OIL IN SYNAPRENE 1712

Base Recipe

S-1712	100	St. acid	1.5
HAF	60	A.O. IPPD	1
Naph. Oil	Varied	MBT	0.75
Zinc Oxide	3	MBTS	0.75
		Sulphur	1.8

Compd. No.	1	2	3	4	5
Naph. Oil	Nil	10	15	20	25
Cure @ 152°C mins.	15	15	15	15	15
T.S.	186	180	177	170	162
E.B.	350	450	525	600	640
Mod. 100%	29.6	19.5	16	12	11.8
Mod. 300%	162	112	82	68	61.5
Hardness	67	62	58	52	48
Tear S	53	49	46	43	41
Comp. Set	20	23	25	25.5	27
Abr. loss	0.53	0.46	0.93	1.08	2.04

COMMENTS:

(1) Tensile strength, modulus, hardness and tear strength drop as the oil level increases.

(2) Ultimate elongation increases with increased oil loading.

(3) Comp. set and abrasion resistance deteriorates with increased loading in oil, but up to 15 phr the effect is marginal on most of the properties.

(4) Economical compounds are possible with oil loading.

TABLE 20
EFFECT OF HARD AND SOFT CLAY IN SYNAPRENE 1502

Base Recipe

S-1502	100	St. acid	1.5
China clay	Varied	A.O. S.P.	1.0
Naph. oil	8	MBTS	1.5
Cumar	7	TMTD	0.5
ZnO	4	Sulfur	2.0
		*DEG	Varied

Compound No.	1	2	3	4	5	6
Soft Clay	80	—	130	—	200	—
Hard Clay (Alkali washed)	—	80	—	130	—	200
ML4	39	37	45	59	59	64
MS	27'12"	19'52"	25'30"	12'15"	19'19"	13'56"
Cure at 152°C	20'	20'	20'	20'	20'	20'
*For every 100 phr China Clay 1 phr of DEG was used.						
T.S.	73	140	62	141	46	101
E.B.	975	835	940	800	965	665
Mod. 300%	22	28.2	28	38.6	29	50
Hardness	51	56	62	64	66	74
Tear S.	24	28	30	42	30	46
Comp. set %	39	33	41	38	56	50
Abr. loss	6.2	5.1	5.85	3.76	6.15	4.05
Flex 2A	42	86	13	138	15	143
Flex 2B	33	28	12	63	12	33
Air ageing at 70°C *for* 72 *hrs.*						
△T.S.	— 7	— 3	Nil	— 6	—11	— 2
△E.B.	—14	—13	—18	—10	—15	—19
△Hardness	+ 3	+ 5	+ 3	+ 7	+ 4	+ 6

COMMENTS:

(1) Mooney viscosity rises by increased loadings of both types of clay but at a higher loading beyond 100 phr hard clay imparts high viscosity.

(2) At equal loadings the mooney scorch period of hard clay is lower than that of soft clay, may be due to

TABLE 23

EFFECT OF PRECIPITATED CALCIUM CARBONATE IN SYNAPRENE 1502

S-1502	100	St. acid	1.5
Pptd. $CaCO_3$	Varied	A.O. S.P	1.0
Naph. Oil	8	CBS	1.25
Cumar	7	TMTD	0.25
ZnO	4	Sulfur	2.00

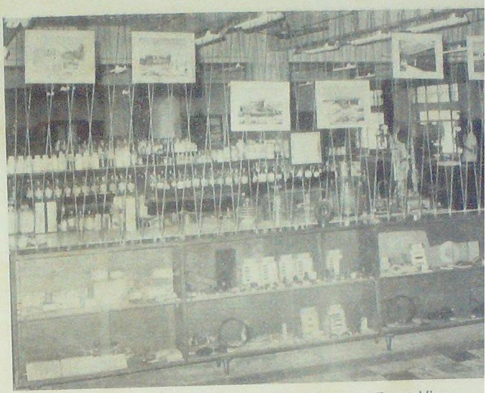
Compd. No.	1	2	3
Ppted $CaCO_3$	80	130	200
ML4 @ 100°C	42	50	75
Cure @ 152°C	10'	10'	10'
T.S.	55	70	61
E.B.	665	650	590
Mod. 300%	16	21	27
Hardness	49	57	68
Tear S.	17	20	26
Comp. Set %	18.4	21	22
Flex 2B	3.4	3.4	3.1
Abr. loss	8.08	7.40	6.94
Bashore R	39	33	23

COMMENTS:

(1) Precipitated Calcium Carbonate is slightly better than soft clay but it is not equivalent to hard clay from the view point of physical properties of the vulcanisates.

(2) Extrusion and calendering characteristics of Ppted. $CaCO_3$ are superior to soft and hard clay at equal loadings.

(3) Compression set characteristics of Ppted $CaCO_3$ are superior to soft and hard clay.



TECHNICAL SERVICE LABORATORY – Front View

PROCESSING SECTION – A

the alkali wash given to it.

(3) Almost same optimum cure timings were achieved by using proportional glycol rather than altering main curatives.

(4) From the development of tensile, tear, elongation, modulus and other physical properties, it is observed that 100 to 130 phr of *hard clay reinforced Synaprenes acting as optimum.*

(5) Soft clay could be utilised for low-modulus-hardness stocks.

TABLE 21
EFFECT OF SOFT CLAY LOADING AT 25 HAF CONSTANT IN SYNAPRENE 1712

Base Recipe

S-1712	100	St. acid	2
HAF	25	A.O. PBN	1
ZnO	4	CBS	1

Compd. No.	1	2	3	4	5
Soft Clay	—	50	100	150	200
Ar. Oil	3	7	11	15	19
TMTD	—	0.05	0.1	0.15	0.2
Sulfur	1.8	1.9	2	2.1	2.2
Cure @ 152°C 35' for all Compounds.					
S.G.	1.04	1.22	1.41	1.53	1.6
T.S.	140	144	125	98	75
E.B.	600	600	600	550	500
Mod. 300%	47	50	52	51	48
Hardness	48	56	62	67	69
Tear S	40	33	30	28	27

COMMENTS:

(1) At low modulus and high elongation (almost constant) compounds having various T.S. are possible with increased soft clay loading.

(2) Such compounds are useful for mechanical moulded goods of varying hardness and T.S. The cure tim-

ings could be shortended by increasing the curative levels with care.

TABLE 22

EFFECT OF HYDRATED SILICA AND CALCIUM SILICATE IN SYNAPRENE 1502

S-1502	100	ZnO	5
Hydrated Silica (Lab-development)	Varied	St. acid	1.0
		DEG	Varied
or		MBTS	1.5
Calcium Silicate (Lab. development)	Varied	TMTD	0.1
Cumar	15	Sulfur	3

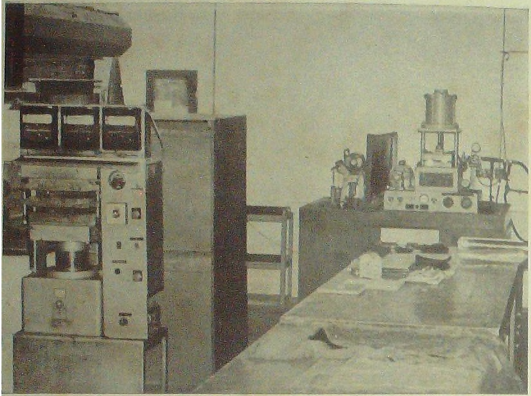
Comp. No.	1	2	3	4	5	6
Silica (Hydrated)	40	60	80	—	—	—
Calcium Silicate	—	—	—	40	60	80
DEG	2.4	3.8	5	2.4	3.8	5
Cure @ 141°C	45'	45'	45'	45'	45'	45'
T.S.	174	202	190	108	122	118
E.B.	615	560	530	630	710	670
Mod. 300%	41	69	87	33	41	49
Hardness	64	75	80	63	69	73
Tear S.	44	46	48	33	35	36.5

COMMENTS:

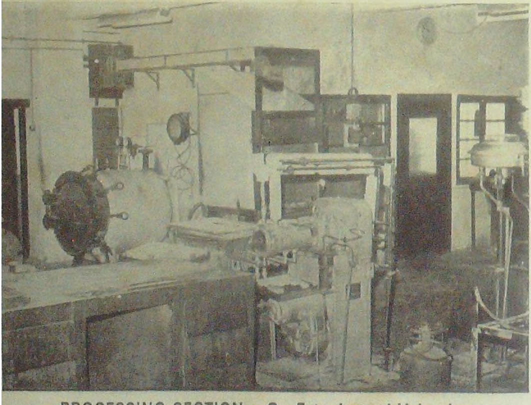
(1) 50-60 phr of Hydrated Silica or Calcium Silicate is the optimum loading for the highest tensile strength.

(2) Modulus, hardness and tear strength increase by increasing these fillers. However, the modulus values are low in comparison with r/f Blacks.

(3) Hydrated Silica imparts much higher tensile and tear strength in comparison with Calcium Silicate.



PROCESSING SECTION – B, Press and Mooney Viscometer



PROCESSING SECTION – C, Extruder and Vulcaniser

TECHNICAL SERVICE LABORATORY

INTRODUCTION:

The Technical Service Laboratory of Synthetics and Chemicals Ltd. was conceived almost at the time of preparing the project report for the Plant to manufacture 30,000 tons per annum of Synthetic rubber. Every effort was made to establish the Laboratory as soon as possible, with the result that even prior to the commencement of production, the Laboratory was opened on February 11, 1963.

We have now completed nine years of our services to the industry and it is, therefore, befitting that we review our progress and present to you the broad outlines of service rendered in the past. We sincerely hope that you will enjoy reading the following few pages highlighting the details of our existing facilities and the types of service rendered.

The laboratory occupies a working area of 8,000 sq. ft. and has all the facilities expected of a laboratory of its kind.

For the sake of convenience, we have five major departments operating within the laboratory as listed under.

1. Rubber Processing Department.
2. Physical Testing Department.
3. Chemical Testing Department.
4. Latex Processing Department.
5. Technical Intelligence.

1. RUBBER PROCESSING DEPARTMENT:

The rubber processing department is a miniature rubber factory by itself. The laboratory has acquired the following equipment.

1. A 1000 cc. Banbury with temperature recorder and variable speeds for fast accurate mixing.
2. A two roll (15 x 30 cms) mixing mill.
3. A three roll (15 x 30 cms) calender with variable speed drive.
4. A two daylight (60 x 60 cms) 150 ton hydraulic steam-heated press equipped with automatic temperature recorder and controller system.
5. A (30 cm x 30 cm), 50 ton hydraulic press, electrically heated platens with thermo-controls.
6. A 3.8 cms variable speed (20 to 80 RPM) extruder.
7. A 76 x 91 cm. jacketed vulcanizer with automatic temperature recorder and controller system.
8. Standard ASTM moulds for moulding test pieces for (a) tensile testing (b) Compression Set test (c) Demattia flex test (d) Ross flex test and (e) Abrasion Test.
9. Moulds for manufacture of microcellular shoe soles, moulded shoe soles, rubber mats, floor tiles, rubber balls and such other miscellaneous rubber goods.
10. 15 x 40 cm two roll shoe-sole embossing calender.
11. Desma Model 203 direct moulding shoe machine (D.V.)

UTILITIES:

1) A Pentax electrical steam generator having evaporation capacity 125 lbs/hr at 100 psi working pressure. 2) A 5 c.f.m. air compressor with an air accumulator unit. Pressure range 125-130 psi.

As will be seen from the list of equipment, the laboratory is fully equipped in all respects and can handle any problem regarding processing.

2. PHYSICAL TESTING DEPARTMENT:

The physical testing department is well equipped with the following:

1. Instron multipurpose tester for stress-strain, hysterisis, etc. properties with automatic recording devices and variable speed drives.
2. Dupont Abrader.
3. Getty flex (Demattia type) with oven to carry out flexing at any desired temperature.
4. A Bashore Resiliometer.
5. A Ross flex tester.
6. Shore durometers for hardness testing.
7. STI Mooney machine pneumatically operated for study of plasticity and scorch behaviour of compounds.
8. Scotts ageing block.
9. Ageing Ovens.
10. Latex stability tester.
11. I.R.H.D. & Micro hardness tester.
12. Izod Impact tester.
13. High voltage tester to test the dielectric strength and breakdown voltage of rubber vulcanizates upto 30 KV.
14. Megohm bridge for testing of insulation resistance.
15. Tension set apparatus.
16. Compression set apparatus both, at constant load and at constant deflection.
17. Hose adhesion tester.
18. Wallace Tackmeter.
19. Infra-red spectrophotometer.
20. Oscillaling disc rheometer.
21. Densimeter.
22. Wallace rapid plastimeter.
23. Dunlop tripsometer.
24. Ozone test chamber.
25. Low temp. flexibility tester.

The following tests on the vulcanized rubber can be carried out with the help of above equipments as per I.S.I., B.S.S., I.S.O., and ASTM standards.

1) Compression deflection characteristics. 2) Compression set. 3) Demattia flex test (dynamic fatigue test and ply separation). 4) Ross flex test. 5) IRHD, Shore (A & D) Hardness. 6) Volume change in liquid medium 7) Rebound resilience. 8) Tension testing (modulus, ultimate tensile strength and elongation at break). 9) Tear resistance (Angle & Crescent type). 10) Tension set. 11) Ageing in air at elevated temperature by Geer Oven or after immersion in liquid medium by Aging Block. 12) Abrasion resistance by Dupont abrader. 13) Adhesion between rubber and fabric. 14) Insulation resistance.

(a) Volume Resistivity.
(b) Surface Resistivity.

15. Dielectric strength of vulcanized rubbers.
16. Specific gravity.
17. Cross-link density.
18. Rigidity modulus (low temperature flexibility test).

Additional testing facilities on unvulcanized compounds are also provided.

1. Mooney viscosity.
2. Mooney scorch time.
3. Mooney cure rate.
4. Extrudability (Garvey die extrusion).
5. Green tack by Wallace tack meter.

3. CHEMICAL TESTING DEPARTMENT:

The section is well equipped to carry out all the chemical testings necessary in a rubber factory, having technical personnel, sophisticated apparatus and instruments.

The following tests are usually asked for:

(1) Bulk density. (2) Oil absorption. (3) Quantitative determination of rubber poisons and other impurities, (4) Qualitative analysis for Polymer identification. (5) Determination of acetone extract. (6) Determination of chloroform extract. (7) Determination of alcoholic KOH extract. (8) Determination of carbon black content. (9) Determination of ash content and analysis of the ash. (10) Determination of Rubber hydrocarbon content. (11) Determination of pH of water extracts etc. (12) Thin layer Chromatographic analysis and (13) Infra-red Analysis of polymeric materials.

4. LATEX PROCESSING DEPARTMENT:

This department has all the facilities for testing rubber latices and for making the latex foam.

The tests that could be carried out are:

1) Total solids content. 2) Dry rubber content. 3) Total alkalinity. 4) KOH number. 5) Mechanical stability. 6) Copper and Manganese content. 7) Coagulum content.

The department also has the facilities such as Jar mills, Hobart Mixers, Moulds, etc., for preparation of the latex foam and other dipped goods on laboratory scale.

5. TECHNICAL INTELIGENCE:

The rubber industry the world over is so far advanced that it is difficult for any individual to keep pace with the rapid technological advances. While individuals might attempt to do this, our Technical Service Laboratory has all the facilities in this respect, so that the latest techniques, either in compounding or new developments taking place elsewhere in the world are available from us at a short notice. In order to achieve this, we have an up-do-date "Special Library" containing more than

165 books on Rubber Technology and other related subjects. Apart from this there is a constant communication with the rest of the world by way of exchange of information. We also receive plenty of trade-literature on products related to the Industry. The list of books available and the magazines subscribed regularly may be had on enquiry. You are welcome to use this library.

CUSTOMER SERVICE:

The following types of services are offered to the industry:—

1. Compound and Product Testing.
2. Handling customers' problems regarding manufacturing process.
3. Handling customers' enquiries on any subject related to rubber.
4. Training courses for rubber technologists from the industry.
5. Rendering field technical service at factory premises.
6. Service Bulletins showing formulae and recipes on a variety of products.
7. Assistance to new entrepreneurs.
8. Participation in the various technical activities.
9. Development of new products to substitute and/or supplement imported products.

1. PRODUCT-TESTING FOR THE CUSTOMERS:

While the rubber consuming industry is, of course, very anxious to carry out their own testing, there are occasions when many factories may not have all facilities and naturally our facilities are at their disposal.

Since last nine years, some 300 customers have sent more than 1,200 compounds or products for testing. This is indeed a very healthy sign reflecting the consciousness of the industry in regard to quality.

2. HANDLING CUSTOMER'S PROBLEMS REGARDING MANUFACTURING PROCESS:

As one can imagine, these problems can be of varied nature. Generally speaking, the problem is to obtain recipe or suitable formulations to meet the requirements of various Indian or international standards. We have facilities available to check the quality to meet the various specifications such as ISI, Defence, BSS, ASTM, SAE, DIN and Russian standards.

3. HANDLING CUSTOMER'S ENQUIRES:

In view of the fact that the rubber industry in India is of a comparative recent origin, there are many queries which are received from the industry. The problem can be regarding the compounding technique the processing technique or curing methods or the testing of a finished product. All these queries have been successfully answered, whereby the customers can take advantage of the know-how without any charge and manufacture the desired product with utmost economy.

4. TRAINING COURSES FOR RUBBER TECHNOLOGISTS:

Unfortunately, our country does not offer yet the professional diploma or degree course in rubber technology except for one or two Institutions. It is not always possible for a technician to attend full time university courses due to limited admissions or due to the fact that very few universities in India offer the course in Rubber Technology. It was therefore felt that the technicians working in the rubber factories could be well trained by the laboratory and with this objective various training courses are conducted from time to time. It is very encouraging that such courses have been very well received. Attempts are made to make the courses well rounded where by in a short period of time, one could acquire some knowledge of rubber technology which would be helpful to the industry.

While we cannot claim to be a regular training college, but atleast as conditions are today, we fulfil the job very satisfactorily and as the process of imparting the knowledge is never complete, we also hope to continue these courses as long as there is enough response. Till now 175 Industry personnel have taken advantage of this activity.

5. FIELD TECHNICAL SERVICE:

Many a time, customer faces a problem peculiar to his factory set up. For this it is necessary to render, on the spot service. Our technical officers who are strategically located through out the country, are always at the disposal of the customers to help them solve the problem on the spot. Technical officers carry out trials to satisfy the customer and if necessary send the sample for evaluation at the laboratory. Laboratory in turn evaluates the products and despatches the laboratory test report to the customer with necessary instructions and comments. Sometimes technical officer finds it necessary to direct the inquiry to laboratory so that the product could be developed or necessary information could be collected from literature so as to assist the customer fully. If the information is not available with the library, an effort is made to obtain necessary information from the foreign sources. Thus no efforts are spared to provide necessary information to the customers at the earliest possible.

6. SERVICE BULLETINS

It is our regular practice to bring out more and more information on the rubber products' development carried out in the laboratory in the form of Service Bulletins. The bulletins include formulations and test data on the product, with necessary instructions on processing.

We also bring out Synaprene News. This includes general information pertaining to the rubber industry in India as well as collected information from the published literature such as foreign technical magazines, technical books etc. We have maintained a regular mailing list of rubber technologists and other dignataries for posting these publications. We regularly mail these bulletins throughout the country. Even the remotest part of the country have access to such facilities.

7. ASSISTANCE TO NEW ENTREPRENEURS:

To start the project, one requires detailed information, on that particular product. In foreign countries the preparation of project report is carried out by commercial consultancy services. In India these services are not yet available to the extent they are in developed countries. Therefore, it was thought fit, that our laboratory help the entrepreneurs desirous of starting rubber manufacturing unit, by providing data to him in all aspects of the project i.e. with respect to plant layout, equipment requirements, production problems etc. Thus our laboratory takes keen interest in providing the nucleus of inforamtion based on which an entrepreneur can set his factory. In this connection our laboratory has published number of project reports on various products.

8. PARTICIPATION IN TECHNICAL ACTIVITIES:

In order to keep ourselves abreast and render assistance in the establishment of new specifications etc., we actively participate in a variety of national and international standards organizations. We play our humble part in assisting ISI, ISO and Defence organizations by way of carrying out inter and intra laboratory testings for various raw materials and finished products. Standardisation is a slow process, once the standards are established for various raw materials and once the standard raw materials are made available, Technologist will be in a position to get the finished product to meet the desired specification and he could also maintain quality control. We also very actively participate in the technical seminars organised by various rubber-bodies by presenting technical papers.

9. DEVELOPMENT OF NEW PRODUCTS :

There are certain raw materials which are not yet produced in the country. In keeping with the basic objective of import substitution, our laboratory has tried to develop, both, on laboratory and commercial scale raw materials based on indigenous sources to replace the imported products. It is hoped that this process will finally bring the country at a situation where we can be completely self-sufficient for all the raw materials required by rubber industry. Apart from substitution programme there are certain occasions where the products have to be supplemented, for example the nitrile rubber at the moment is imported, for making the optimum use of the limited quantity of Nitrile rubber, we have thought of substituting this product by blending PVC/Nitrile and Synaprene rubbers so that the quantum of Nitrile rubber imported can be made to last longer with the help of locally produced PVC.

The technical service laboratory has developed the most required ten chemical compounding ingredients. The Standard Ross-Flex type of flexing machine, generally used by the foot-wear industry, has been developed to suit Indian Rubber Industry.

The technical service laboratory works in full co-ordination with the Plant in all respects so that it also functions as a development laboratory for the Plant. Such close co-ordination is extremely vital for the manufacturing industry as before the products are finally available for sale, every aspect is carefully checked at every stage so that our customers can get the very best that we can offer.

SYNAPRENE RUBBERS IN TYRES

Synaprene rubbers are widely used in the tyre industry. This includes automobile, truck and tractor tyre fields. Passenger treads could be advantageously compounded for improvement in tread-wear and flex-life with Synaprene 1500 and/or Synaprene 1712. Synaprene stocks show excellent heat-ageing and oxygen-ageing resistance, together with excellent flex-life and resistance to ply-separation for passenger carcass stocks. Black and white side-walls for passenger tyres, based on Synaprene Rubber or blends with Natural Rubber offer good resistance to weathering, age-cracking and radial-cracks due to flex-fatigue. Bright white coloured stocks for side-walls with consistency could be easily developed with Synaprene 1502. For improvements in ozone-resistance, Synaprene Rubbers could be blended with co-curing type of EPDM.

The ratio of blending of Synaprene Rubbers to Natural Rubber for truck treads is largely governed by the service for which the tyre is intended and its size. For a small size or where service is not expected to be very rigorous, a tread of cent percent Synaprene could be used. For tread-wear, heat build-up and tread-cracking resistance blends should be thoroughly studied and by compounding, process and construction techniques larger proportions of Synaprene Rubbers could be used for truck treads, side-walls and carcass stocks.

Bead wire insulation compounds with Synaprene Rubbers offer various advantages in processing and tyre-performance. Uniform and cool extrusion lower scorch-hazard and excellent uncured adhesion are imparted by Synaprene Bead compounds. Excellent after cure characteristics like high adhesion to bead wire, no reversion, no danger of metal-poisoning due to copper and balanced age-resistance are the bonus points for such compounds.

TRUCK TREAD

Compd. No.	1	2	3	4	5
S-1500	—	10	15	20	30
RMX 1X	100	90	85	80	70
ISAF	20	20	20	20	20
HAF	24	24	24	24	24
Ar. Oil	5	5	5	5	5
Zinc Oxide	5	5	5	5	5
A.O. Ketone-Amine	1	1	1	1	1
A.O. IPPD*	1	1	1	1	1
P. Wax	1	1	1	1	1
St. Acid	2.5	2.5	2.5	2.5	2.5
TBBS	0.5	0.5	0.5	0.6	0.65
Sulphur	2.5	2.5	2.5	2.4	2.35
Retarder NDPA	0.3	0.3	0.3	0.3	0.3
S.G.	1.13	1.13	1.13	1.13	1.14
ML4	58	60	58	56	51
MS @ 143°C	7'37"	8'25"	8'30"	9'	9'12"
Cure @ 141°C	35'	35'	35'	35'	35'
T.S.	305	308	307	297	280
E. B. %	575	550	550	550	525
Mod. 100%	22.7	25	24	24	24
Mod. 300%	130	146	136	137	129
Hardness	61	64	64	64	65
Tear S.	93	75	73	73	53
Bashore R.	45	45	45	44	44
Flex 2A	33	69	260	132	131
Flex 2B	29	31	28	25	16.3
Abr. Loss	2.0	1.62	1.61	1.54	0.93
Heat Generation** °C for 100 K.C.	92	94	95	96	96

*Recent trend is to use water non-leaching antiozonants like Alkyl-aryl p-phenylene-diamine.

**Fatigue Bend Testing Machine — Model DPG I VEB Thuringar Industriwerk Rauenstein.

Radius of Curvature of Bend: 45 mm.

PASSENGER TREAD

DU/5970/A	1	2	3	4
S-1712	100	100	50	70
S-1500	—	—	50	—
EBR-OE	—	—	—	30
ISAF	—	20	—	20
HAF	50	40	60	40
Ar. Oil	3	10	10	10
Zinc Oxide	4	4	4	4
St. Acid	2.5	2.5	2.5	2.5
PBN	1	1	1	1
A.O. IPPD*	1	1	1	1
P. Wax	1	1	1	1
CBS	0.8	0.8	0.8	0.60
DPG	0.2	0.2	0.2	0.20
Sulphur	1.8	1.8	2.0	1.5
Retarder NDPA	0.3	0.3	0.3	0.3
S. G. (Actual)	1.15	1.65	1.16	1.15
ML4	50	52	47	48
MS	19'30"	22'5"	22'25"	25'
Cure @ 152°C	20'	20'	20'	30'
T.S.	214	208	217	167
E.B.	500	500	530	550
Mod. 300%	107	110	98	77
Hardness	60	60	62	59
Tear S	51	48	52	42
Bashore R	31	25	32	31
Flex 2A	>200	>200	>200	>200
Abr. Loss	0.99	0.97	0.86	0.64
Air-Ageing @ 100°C for 3 days.				
△T.S. %	—27	—17	—21	—23
△E.B. %	—48	—49	—50	—49
△ Hardness	+ 10	+ 10	+ 7	+ 9

Note: Above passenger treads are also recommended for Truck Treads upto 8.25-20 size.

*Recent trend is to use water non-leaching antiozonants like Alkyl-aryl p-phenylene-diamines.

TRUCK-TYRE CARCASS

	Inner Plies		Outer Plies	
DU/5970/D	1	2	3	4
S-1500	30	40	10	20
RMA IX	50	40	80	80
WTR	40	40	20	—
FEF	25	25	25	25
ZnO	4	4	4	4
St. Acid	1.5	1.5	1.5	1.5
A.O. Ketone-amine	1	1	1	1
A.O. PBN & DPPD	1.5	1.5	1.5	1.5
MBTS	0.6	0.7	—	—
CBS	—	—	0.6	0.7
DPG	—	—	0.2	0.2
Sulphur	2.2	2.2	2.0	2.0
ML4	32	31	29	30
MS	16'45"	18'32"	15'20"	11'50"
Cure @ 152°C	25'	25'	25'	25'
T.S.	144	143	179	182
E.B.	585	600	610	575
Mod. 300%	57	56	51.5	51
Hardness	53	57	51	50
Flex 2A	87	—	85	87
Flex 2B	210	159	98	125
Ageing @ 70°C for 7 days.				
△T.S.	+ 3	—1	—13.5	—13.1
△E.B.	—17	—21	—23	—17
△Mod. 300%	+ 36	+ 39	+ 42	+ 26
△Hardness	+ 4	+ 4	+ 4	+ 2

*Suitable carcass-stock could be selected for passenger tyres also.

TYRE BEAD INSULATION COMPOUNDS

High tensile steel wires (beads) are vital for all types of pneumatic tyres. Basically the principal function of the bead is to hold the tyre against the rim. The beads are insulated by a rubber compound with the help of an extruder. Insulated bead-core assembly consisting of multiple strands, should adhere properly to bead-flipper and rubberised square-woven fabric.

To get better adhesion, the compounds of bead-insulation should be properly designed so that during the service life of a tyre, the compound hardens slowly and does not leave the bead. Synaprene rubber compounds have inherent characteristic of hardening and this typical property could be well exploited here in the case of Bead Insulation compounds.

	1	2
Synaprene 1500	100	—
Synaprene 1712	—	100
SRF Black	70	70
Naph. oil	5	5
Rosin oil	5	5
ZnO	10	10
St. acid	2	2
A.O. PBN	1.5	1.5
MBTS	1.7	1.6
Sulfur	10	7
ML4	49	36
MS at 126°C	19'07"	17'30"
Cure @ 140°C	40'	40'
Hardness	75	70
Aged Hardness 72 hrs. @ 100°C	88	81

TYRE SIDE WALL COMPOUNDS

	Truck		Passanger		Sidewall*
DU/5970/B	1	2	3	4	5
Synaprene 1500	—	—	—	—	70
Synaprene 1502	100	25	50	30	—
Synaprene 1712	—	—	50	—	—
NR	—	75	—	70	30
HAF	—	—	—	—	45
SRF	60	60	60	—	—
Pptd. $CaCO_3$	—	—	—	10	—
China clay	—	—	—	20	—
Cumar	5	—	—	—	—
H. Ar. Oil	—	—	—	—	7
Naph. oil	5	5	10	3	—
Zinc oxide	4	4	4	20	4
St. acid	1.5	1.5	1.5	1.5	2.5
A.O. PBN	1	1	1	—	1
A.O. IPPD	1	1	1	—	1
A.O. SP	—	—	—	1.5	—
Micro wax	1	1	1	1	1
CBS	0.7	1	1	—	0.9
MBTS	—	—	—	1.5	—
DPG	—	—	—	0.15	—
Sulfur	2.25	2	1.6	2.5	1.8
TiO_2	—	—	—	qs	—
ML4	48	40	39	35	44
MS	22'40"	13'45"	22'	14'45"	18'10"
Cure at 152°C	20'	20'	20'	20'	30'
T.S.	166	197	151	214	260
E.B.	540	475	650	650	600
Mod. 300%	89	112	62	35	89
Hardness	58	58	54	48	58
Tear S	55	48	49	31	—
Flex 2A	57	68	164	67	67.5
Bashore R	—	—	—	—	42
Abr. loss	—	—	—	—	1.29

*Note : Compd. 5 has Common Tread & Sidewall.

SCOOTER AND MOTOR CYCLE TREADS

	1	2	3
S-1712	100	100	80.0
RMA 1X	—	—	20
HAF	50	62	50
H. Ar. Oil	3	10	3
Zinc oxide	4	4	4
St. acid	2	2	2
A.O. PBN	1	1	1
A.O. IPPD	1	1	1
P. Wax	1	1	1
TBBS	1.0	1.0	0.9
DPG	0.2	0.2	0.2
Sulfur	1.75	1.8	1.9
S.G.	1.13	1.19	1.13
ML4	44	47	46
MS	24'30"	19'18"	19'9"
Cure @ 152°C	20'	20'	20'
T.S.	202	192	210
E.B.	460	425	440
Mod. 300%	115	131	129
Hardness	60	61	60
Tear S	53	67.5	55
Flex 2A	174	> 150	164
Abr. loss	1.21	1.33	1.29
Air ageing @ 70°C for 7 days.			
△ T.S.	— 4	— 2	— 7
△ E.B.	—20	—18	—20
△ Hardness	+ 4	+ 3	+ 3

CAMELBACK AND RETREAD MATERIALS

A retread compound (camelback and slab) is expected to give the same performance as the original tread which it replaces. However, certain characteristics of the original tread compound, are not so vital for the retread compound. The casing is fully grown, hence the prime reason for tread-cracking is eliminated. Heat build-up and tread-separation are not much of a problem. Hence the better abrasion or wear-resistance property of Synaprene could be economically exploited for these camelback compounds.

Especially oil-extended Styrene-Butadiene and Emulsion-Polybutadiene Rubbers like Synaprene 1712 and EBR-OE are very popularly used for the manufacture of camelback compounds. It is practicable to design low cost camelback compounds based on higher loading of carbon-black and oil without much sacrifice in the product performance or its service life.

A retread compound is expected to have a long storage life. The scorch resistance of Synaprene Rubbers aids in materially increasing the storage-life of the retread compound even when compounded with the scorchy furnace blacks.

Synaprene 1500, Synaprene 1712 and Synaprene EBR-OE are the preferred rubbers for this application. Synaprene 1500 gives vulcanizates with better resistance to tear and is preferred for truck tyre retreads and premium passenger retreads. Synaprene 1712 is generally used for passenger tyre retreads because of better traction, wet-skid resistance and silent running. Synaprene EBR-OE is preferred because of very high abrasion, flex and age resistance. For passenger retreads, EBR-OE is blended with S-1712, while for truck retreads, EBR-OE is blended with NR. Physical properties do not fall on gross over-cures or during service because of the unique property of EBR-OE to arrest reversion of NR. EBR-OE also maintains the tack of NR in blends.

All these three polymers give excellent abrasion resistance as retread compounds. Furnace Blacks such as HAF and ISAF give superior performance than Channel Blacks in Synaprene Rubbers.

OIL-CARBON BLACK EXTENSION :

For better economics, Synaprene Rubbers can be extended with oil and furnace blacks. The following can be used as the guide-line :

(i) For every phr HAF above 50 phr loading in Synaprene 1500, 0.8 part extra oil is added.

e.g. ..	Synaprene 1500	100	100
	HAF	50	6~~9~~2.5
	Aromatic Oil	8	18

(ii) Similarly, for every phr HAF above 50 phr loading in Synaprene 1712, 1.00 part extra oil is added.

eg. .	Synaprene 1712	100	100
	HAF	50	62.5
	Aromatic Oil	3	15

This will maintain the hardness, modulus and the stiffness of the compounds to the level of those of the conventional compounds.

USE OF INSOLUBLE SULPHUR :

Insoluble sulphur is used in retread compounds for two reasons viz :—

(i) To reduce the blooming of sulphur, and

(ii) To increase the storage life of the products.

Retread compounds contain sulphur at 2-3 phr level. Sulphur at this level is soluble in rubber at the mixing temperature. But at room temperature, the solubility of sulphur in rubber falls to only 0.7 phr.

Hence the excess blooms out slowly and kills the surface tack of the retread compound. The bloom cannot be removed by solvent swab. This leads to the difficulty in building up and the proper fusion of retread to the casing.

Insoluble sulphur is inactive and does not cross-link with rubber till at 90°C, at which temperature it gets converted to ordinary active form, hence during the processing stages or during storage, the temperature of the rubber stock should not reach upto 90°C., the compounds containing insoluble sulphur can be stored for long period.

Experiments were carried out in our T. S. Laboratory on the effect of use of normal sulphur in the Synaprene rubber camelback compounds.

Following two compounds were prepared and stored at room temperature for 8 months in Bombay (February to October) packed in polythene liners. They were checked for blooming and the Mooney Scorch time.

Synaprene 1500	100	—
Synaprene 1712	—	100
ISAF	—	12.5
HAF	50	37.5
Aromatic Oil	10	8.5
Zinc Oxide	3.5	3.5
Stearic Acid	2.0	1.5
PBN	0.5	0.5
CBS	1.2	1.0
Sulfur	2	1.5
Mooney Scorch time (minutes to 5 points rise)		
Original	39	25
After 32 week's storage	32	23

In the case of Synaprene 1712 retread compounds, there is no blooming tendency present even if soluble sulphur (Normal Rubber grade Sulphur) is used. This fact coupled with scorch resistance of Synaprene rubbers makes it possible to use normal soluble sulphur in Synaprene 1712 compounds which are to be used within a reasonable period.

CUSHION GUM : Synaprene Rubbers exhibit slightly lower building tack compared to NR compounds. But the use of natural rubber cushion-gum eliminates, building-up difficulties and the fusion of the retread with the casing is excellent

When Synaprene 1712 is used or when high carbon black-oil loadings are used in Synaprene 1500, it is found advisable to aim for a slightly higher modulus in the cushion-gum compound to off-set any softening of the cushion-gum by migration of oil from retread compound to the cushion-gum. This can be achieved by using slightly higher carbon black loading or by the use of higher structure black in the compound.

The recent trend abroad is to replace a part (10%) of the natural rubber by the oil extended polymer like SBR 1712 and extend the cushion-gum compound too, by use of higher loading of carbon black and oil (e.g. instead of 100 NR; 30 FEF; 5 Oil; use of 90 NR; 13.5 SBR 1712; 50 FEF; 20 Oil is made).

PROCESSING OF SYNAPRENE RETREAD COMPOUNDS :

Instructions for "detailed processing" are already given in the section "Processing of Synaprene Rubbers". These instructions hold good for retread compounds also. In addition, the following points should not be overlooked:

(1) If a single polymer is used, the normal mixing sequence could be used.

(2) For blending of two or more polymers, master-batch mixing-technique should be used. For Synaprene 1500 and 1712, master-batch with 50 phr HAF with 7 to 3 phr Aromatic processing oil could be conveniently prepared. But to achieve best dispersions with EBR-OE (40 ML4) master-batch with 65 to 70 phr HAF with 5 phr H. Ar. Oil should be prepared.

(3) To get the best homogenity of the blends, the mooney viscosities of the polymers or master-batches should be near-about the same while blending.

The Mill-mixing cycle for a single polymer should be :

(1) Pass polymer two time through tight nip for quick banding.

(2) Zinc Oxide, Anti-Oxidants and anti-ozonants.

(3) 2/3 carbon black + stearic acid.

(4) 1/3 carbon black + oil + paraffin wax.

(5) Accelerators (Sulfenamides) and sulphur on a cool mix.

The former practice (in the days of natural rubber and MPC) was to add the accelerator MBT to the rubber in the initial stages. MBT acts as a mild peptiser for natural rubber. But at present, with the basic furnace blacks, sulfenamide type accelerators are preferred. These accelerators do give safe processing stocks so long as they are not decomposed, by high temperatures. Once decomposed, these accelerators give very scorchy stocks. Mill temperatures are likely to go above the decomposition point of the sulfenamide accelerators during the carbon

In the case of Synaprene 1712 retread compounds, there is no blooming tendency present even if soluble sulphur (Normal Rubber grade Sulphur) is used. This fact coupled with scorch resistance of Synaprene rubbers makes it possible to use normal soluble sulphur in Synaprene 1712 compounds which are to be used within a reasonable period.

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In Banbury mixing also, it is preferable to add the accelerator and sulphur on the slab-off mill rather than in the Banbury. If it cannot be done on the mill it is preferable to resort to two-step mixing i.e. in the first step a master-batch of all the ingredients except the curatives is made, and on cooling, next day, in the second step the curatives are added to the masterbatch in the Banbury. This two-step mixing also gives a better dispersion of black and better control on the carbon-gel content.

As mentioned earlier, it is preferable to add zinc oxide and stearic acid separately at two different stages of mixing. Simultaneous addition of the two has been found to give improper dispersion of the zinc oxide.

On mill, the carbon black addition should preferably be made at thin nip setting, atleast in the early mixing cycle to avoid bagging. Once the mix attains sufficient green strength, the nip could be opened.

The slab material can be produced directly from a mixing mill. With Synaprene compounds, it is difficult to take out a thick sheet like 14/32" from the mill because of bagging difficulty and consequent air entrapment. In such cases, it is preferable to roll out bundles of the compound keeping a very thin nip. The nip should be then widened, the bundles fed to the nip vertically and the sheet taken out without allowing the band to form.

There is also another technique to sheet out a smooth thin sheet without air-entrapment. First a thicker sheet may be rough or smooth but without air pockets should be slabbed off (warm) and then the thin sheet could be straight rolled off the mill without banding. Here again, it is not possible to take out good-lengths.

During recent years, retreading operations are shifting towards automation. In U.S.A., changes in machines materials and methods have lead to faster production and considerable saving in the economy in the retread business. In some shops, the use of extruders is eliminated and the tread is directly slabbed off from the special mills in the required width and thickness by a pair of knives. Such slabs are sprayed with adhesives and the need for cushion gum is eliminated.

Conventional rubber extruders are superceeded by 6 inch hot-feed extruder which has a "veraco" head with adjustable dies to change tread rubber width and crown for various passenger and truck tyre sizes, but such equipment is very expensive.

Yet another process that has already established its place in retreading shops is the Orbitread process where a ribbon of tread is extruded directly on the buffed cemented casing and wound helically. This process elimintaes the need for cushion gum and splicing of tread is not required. Depending on the type of machine, Orbitread series can handle sizes ranging from passenger to highway tyres.

In Heintz process, a cold strip is applied to the casing instead of a hot strip of tread. There are several inherent advantages in using cold strip building method. The application of the cold strip to the carcass in multiple is by overlapping passes across the tyre which allows potentially trapped air to dissipate more readily as the rubber is being stitched to the carcass. The use of cold tread strips reduces the danger of set-up or surface lamination cure over that of hot-strip application, especially, in the larger size off-the-road treads where heavy tread stock thickness is required. One such machine GTL-400 made by Heintz, U.S.A. applies as high as 1800 lbs/hour of cold strip over the carcass.

Apart from building operation many changes have been made in the retreading equipment such as molds, matrices and curing equipment.

POROSITY IN EXTRUDED STOCKS : The porosity in extruded stock is generally due to the decomposition of the nitrosoamine type retarders during the high temperature-extrusion. This porosity is also encountered when a cheaper retarder like salicylic acid is used, which is difficult to disperse. Treated phthalic anhydride due to its higher melting point (124°C) creates minimum problems on porosity. Generally, for Synaprene Retread compounds, use of any retarder is unwarranted, but if used, it should be added to the polymer prior to the addition of carbon-black.

The recent trend is to use extruders with vacuum device to avoid porosity in the green extrudate. This helps, particularly, in continuous vulcanization of the extrudates without any porosity.

BUILDING UP : Retreading with Synaprene compounds does not offer any problem when natural rubber cushion-gum is used. It is a practice to make bevel splice but even butt-splicing has been found satisfactory. In such cases a homogeniser tool (an instrument with two metal prongs) is used. The two prongs are inserted in either side of the splice-joint and given a twist to force the edges of the butt splice more tightly.

In the case of Synaprene compounds, the camelback should be applied with no tension to prevent any tendency to spring back and create open splices. This is essential in shops where the built-up tyre is held for an extended time before cure.

CURING : In normal retreading shops in our country, heat for moulding is applied only from outside. The cure-time will depend on the tyre and the thickness of the camelback and the temperatures used for moulding in the shop. A rough guide, for the formulations given, will be 5 minutes at 145°C per 1/32" i.e. a 12/32" camelback will require about 60 minutes to cure.

RETREAD COMPOUNDS FOR TRUCK TYRES

	1	2	3	4	5	6
S-1500	100	100	—	—	—	—
S-1712	—	—	80	60	—	—
S-EBR-OE	—	—	—	—	40	40
RMA 1X	—	—	20	40	60	60
HAF	50	62	50	50	62	30
ISAF	—	—	—	—	—	20
H. Ar. Oil	7	15	3	7	15	9
ZnO	4	4	4	4	4	4
St. acid	2	2	2.5	2.5	2.5	2.5
A.O. PBN	0.5	1	1	1	1	—
A.O. Ketone-Amine	—	—	—	—	—	0.75
A.O. PBN & DPPD	—	—	—	—	—	0.75
CBS	1.1	1	0.85	0.65	0.7	0.56
Crystex sulphur	1.85	2	1.8	2.0	2.2	2.14
S. G. (actual)	1.135	1.15	1.14	1.14	1.14	1.12
ML4	62	58	57	39	42	48
MS	28'41"	26'14"	28'15"	23'25"	20'23"	17'46"
Garvey extrusion $1\frac{1}{2}$" Screw, 50 rpm						
cms/min	352	361	372	352	378	—
% Die swell	43	41	52	68	53.5	—
Cure @ 152°C	25'	30'	20'	20'	20'	20'
T.S.	241	227	250	225	227	221
E.B.	475	465	500	525	500	510
Mod. 300%	135	149	134	108	138	105
Hardness	63	66	61	61	62	62
Tear S	58	49	55	—	—	65
Abr. loss	0.49	0.52	0.66	1.06	0.97	0.77
Flex 2A	>280	>200	>300	>100	133	69
Air ageing @ 100°C for 72 hrs.						
△T.S.	—38	—35	—20	—47	—41	—69
△E.B.	—40	—41	—40	—34	—46	—63
△Hardness	+ 4	+ 4	+ 3	+ 6	+ 5	nil

N.B. Retarder could be added if the safety requirement on extrusion is high.

RETREAD COMPOUNDS FOR PASSENGER TYRES

	1	2	3	4	5	6
S—1712	100	100	80	40	60	—
S-EBR-OE	—	—	—	40	—	60
RMA 1X	—	—	20	20	40	40
HAF	50	62	45	45	50	50
H. Ar. Oil	3	12	12	—	7	7
ZnO	4	3.5	4	4	4	4
St. acid	2.5	2.5	2.5	2.5	2.5	2.5
A.O. PBN	1	1	1	1	1	1
A.O.IPPD	1	1	1	1	1	1
CBS	1.1	1.1	0.85	0.85	0.65	0.55
DPG	0.1	0.1	—	—	—	—
Crystex Sulfur	1.5	1.6	1.8	1.8	2.0	2.15
S.G.	1.14	1.15	1.135	1.135	1.14	1.135
ML4	56	54	55	44	39	46
MS	21' 18"	22' 29"	27'	25' 17"	23 '25"	18' 38"
Garvey extrusion 1½" Screw. 50 rpm Cms/min	360	354	344	350	352	392
% Die swell	61	58	76	78	68	68
Cure @ 152°C	25'	25'	20'	20'	20'	20'
T.S.	202	188	264	205	222	225
E.B.	600	550	550	510	525	530
Mod. 300%	76	90	103	102	108	101
Hardness	58	58	59	58	61	61
Tear S	42	42	51	—	—	55
Abr. loss	0.75	0.83	0.95	0.62	1.06	0.78
Flex 2A	95	>100	>300	>200	>100	83
Air Ageing @ 100°C for 72 hrs.						
△T.S.	—29	—30	—23	—31	—47	—27
△E.B.	—42	—38	—35	—32	—34	—36
△Hardness	+3	+ 4	+ 7	+ 5	+ 6	+ 4

CUSHION GUM COMPOUND

	1	2
RMA 1X	100	70
S—1500	—	30
FEF	30	30
Pine tar	5	5
Cumar	3	5
Zinc Oxide	4	4
St. acid	1.5	1.5
A.O.PBN	1	1
CBS	0.6	0.8
Insoluble sulfur	2.5	2.25
Tack in Gms: (Wallace tackmeter)		
After 1 hour	850	850
After 24 hours	850	850
Calendering :	Excellent	Excellent

AUTOMOTIVE INNER TUBES

Automotive inner tubes for tyres can be divided into two categories: (1) Inner tubes for passenger tyres and (2) Inner tubes for truck tyres. Normally passenger tubes are manufactured using Butyl rubber and truck tubes are manufactured using general purpose rubbers like Natural rubber and blends of natural and SBR.

Butyl rubber offers the best air-retention capacity and excellent age resistance. Next best is SBR. Butyl rubber vulcanisates retain the air 14 times better than NR and SBR (23.5% styrene) retains the air 4 times better than NR, while SBR (40% styrene) retains the air 6.5 times better than NR.

When compounded properly with reinforcing furnace black like FEF the tear strength of tubes of NR, SBR, & Butyl are almost alike. This particular property controls the puncture propagation of a tube.

Inner tube compounds of NR, blends of NR and SBR and Butyl could be compounded for hardness, modulus, elongation and tear properties almost alike but the property of tensile strength varies as per the nature of the polymer (i.e. Crystallinity) e.g. Natural rubber would show higher tensile strength than SBR and Butyl on stretching.

Apart from vulcanisate characteristics, processing characteristics and other requisites of Inner tube compounds are:

(1) Uniform plasticity for trouble-free extrusion resulting in uniform thickness.
(2) Fairly high rate of extrusion for productivity.
(3) Fast cure-rate with adequate processing safety and ability to give fast lap or butt-splicing.

The following two tables show the effect of gradual substitution of NR by Synaprene 1500 and 1712 in the inner tube compounds:

TABLE 24

NR/S–1500 BLENDS FOR INNER TUBES

DU/2470/C	1	2	3	4	5	6
RMA-1X	100	90	85	80	75	70
S-1500	—	10	15	20	25	30
FEF	25	25	25	25	25	25
Ar. Oil	1	1	1	1	1	1
Zinc Oxide	4	4	4	4	4	4
St. acid	1	1	1	1	1	1
A.O. Ketone-amine	1.5	1.5	1.5	1.5	1.5	1.5
A.O. IPPD	1	1	1	1	1	1
P. Wax	0.5	0.5	0.5	0.5	0.5	0.5
TBBS	1	1.05	1.07	1.10	1.13	1.15
Sulfur	2.2	2.16	2.14	2.12	2.10	2.08
S.G.	1.04	1.04	1.04	1.04	1.04	1.04
ML4	26	26	26	25	31	32
M.S.	6'45"	7'10"	7'30"	8'10"	8'15"	9'
Garvey Extrusion:						
1½ Extruder @ 50 rpm.						
Cms/min.	446	450	431	381	368	351
% Die Swell	32	34	41	47	53	60
Cure @ 152°C	7'	7'	7'	7'	7'	7'
T.S.	296	281	284	258	274	271
E.B.	610	580	580	570	600	535
Mod. 300%	78	73	79	73	71	71
Hardness	52	51	51	51	52	53
Tear S, at RT	46	46	47	44	45	42
Tear S, @ 70°C	53	46	43	43	41	41
Air-Ageing @ 70°C for 3 days.						
△ T.S.	+ 5	—3	—4	—4	—2.5	—1
△ E.B.	—10	—13	—12	—14	—13	—11
△Mod. 300%	+ 36	+37	+43	+39	+44	+35
△Hardness	+ 3	+ 6	+ 6	+ 2	+ 4	+ 7

Air-Ageing @ 70°C for 5 days.

△T.S.	—5	—6	—6	—4	—5	Nil
△E.B.	—11	—13	—15	—11	—14	—11.5
△Mod. 300%	+45	+41	+55	+45	+46	+45
△Hardness	+ 6	+ 5	+ 7	+ 7	+ 7	+ 7

Air-Ageing @ 100°C for 3 days.

△T.S.	—33	—39	—33	—36	—39	—33
△E.B.	—28	—35	—35	—32	—52	—30
△Mod. 300%	+53	+53	+66	+56	+71	+58
△Hardness	+ 5	+ 8	+ 9	+ 6	+ 8	+ 8

TABLE 25

NR/S–1712 BLENDS FOR INNER TUBES

Ref: DU/2470/D	1	2	3	4	5	6
RMA-1X	100	90	85	80	75	70
S-1712	—	10	15	20	25	30
FEF	25	25	25	25	25	25
Ar. Oil	1	1	1	1	1	1
Zinc Oxide	4	4	4	4	4	4
St. acid	1	1	1	1	1	1
A.O. Ketone-amine	1.5	1.5	1.5	1.5	1.5	1.5
A.O. IPPD	1	1	1	1	1	1
P. Wax	0.5	0.5	0.5	0.5	0.5	0.5
TBBS	1	1.05	1.07	1.10	1.12	1.15
Sulfur	2.2	2.10	2.09	2.06	2.02	1.99
S.G.	1.04	1.04	1.04	1.04	1.04	1.04
ML4	23	24	26	24	25	26
M.S.	5'15"	7'50"	8'	8'10"	8'15"	8'50"
Garvey extrusion						
1½" Extruder @ 50 rpm						
Cms/min.	446	483	451	402	360	352
% Die Swell	32	35	47	62	68	77
Cure @ 152°C	5'	5'	5'	5'	5'	5'
T.S.	296	298	289	261	276	262
E.B.	610	620	610	600	610	610
Mod. 300%	78	73	67	69	66	69

Hardness	52	50	49	50	49	49
Tear S @ RT	46	47	47	43	44	44
Tear S @ 70°C	53	48.5	45	42	41	42
AirAgeing @ 70°C for 3 days.						
△ T.S.	+ 3	+ 1.8	—4.5	—2.3	—9.6	3.7
△E.B.	—6.6	—8.6	—10	—9	—9	—10
△Mod. 300%	+22	+37	+29	+36	+35	+41
△Hardness	+ 4	+ 4	+ 4	+ 4	+ 3	+ 3
Air-Ageing @ 70°C for 5 days.						
△T. S.	—1	+2.5	—1.75	+3	—9.6	+3.7
△ E.B.	—12	—8	—10	—12	—15	—15.5
△Mod. 300%	+35	+52	+39	+49	+48	+55
△Hardness	+ 4	+ 6	+ 6	+ 5	+ 4	+ 3
Air-Ageing @ 100°C for 3 days.						
△ T.S.	—29	—29	—26	—29	—35	—31
△ E.B.	—25	—27	—27	—33	—35	—35
△Mod. 300%	+54	+55	+52	+59	+58	+61
△Hardness	+ 5	+ 6	+ 6	+ 6	+ 5	+ 4

COMMENTS:

(1) In both the series compounded mooney viscosity are slightly low, may be because of compounds, getting over-worked due to masterbatch-mixing technique. However, due to gradual incorporation of Synaprene 1500 and 1712, there is a minor rise in the compounded mooney viscosity.

(2) Safety in processing improves by gradual rise in synaprene without affecting the cure-rates. (Balanced by pro-rata level of curatives.)

(3) Rate of extrusion comes down slightly due to increase in Synaprene and % die-swell also increases. This calls for die-adjustments. Once the die is ad-

justed for original thickness, the rate of extrusion does not get impaired.

(4) Physical properties of the vulcanisates are not affected much upto 30 phr of S-1500 and S-1712. There is minor drop in tensile and tear strength, but modulus remains almost unaffected.

(5) Tear strength at room temp. as well as at 70°C shows very slow and gradual decrease. However there is no drastic fall of tear strength at 70°C.

(6) Moderate and severe, both types of ageing results, remain almost constant upto 30 phr of S-1500 and S-1712.

(7) To lower the modulus value, levels of accelerator and sulfur should be lowered with slightly higher cure cycle for both the series.

SCOOTER AND MOTOR CYCLE TUBE

A good scooter or motor cycle tube should have very high air-retention capacity, low modulus and high elongation with low hardness.

DU/1871/A	(1)	(2)
RMA 1X	70	70
S-1712	30	—
S-1513	—	30
FEF	20	20
SRF	20	20
H. Ar. Oil	7	10
Cumar	3	3
ZnO	4	4
St. acid	1.5	1.5
A.O. PBN	1	1
A.O. IPPD	1	1
P. Wax	0.5	0.5
TBBS	0.6	0.6
MBTS	0.6	0.6
Sulfur	1.5	1.6
S.G. (actual)	1.10	1.10
Cure @ 152°C	10'	10'
T.S.	217	218
E.B.	650	630
Mod. 300%	57	59
Hardness	49	50
Tear S	42	42.5
Air-Ageing @ 100°C for 72 hrs.		
△ E.B.	—25	—23
△ T.S.	—27	—23
△Hardness	+ 2	+ 3

CYCLE TYRES

At present cycle tyres are manufactured by two methods :

(a) On a multiday-light-press, using curing bag method.

(b) On a Bag-O-Matic press, using curing bladder method.

Tread and carcass compounds for curing bladder method could be advantageously compounded for fast cure-cycle either by higher temperature and/or by taking slightly higher level of curatives 3 to 5 minutes cure-cycle at 165°C is a normal practice. But compounds for multi-day-light presses with curing bag method should have higher safety period against scorch hazard which allows longer down time and the cure cycle is normally 6 to 8 minutes at 155°C.

A cycle tyre compound should have :

1. Uniform plasticity to ensure that the tread which is either extruded or calendered maintains its dimensions within very narrow limits and also plasticity low enough to get sharp mould design details, at low air pressure (7 kg/cm^2), on the cured product.
2. Ability to be cured at high temperature without reversion for faster economic production.
3. Fast cure rates with good processing safety.
4. Good resistance to abrasion, flex and ageing of the vulcanizate.

The formulations given are based on Synaprene rubbers and its blends with natural rubber and reclaim to give a good balance in processing, building and vulcanizate characteristics. These are economic cycle tyre compounds. As the heating is only from outer peripheral side of the mould, the carcass compound for such curing system should be designed for fast cure. The cure rate of the carcass compound should be one and half times faster than the tread compound to get balanced cure for the composite unit and optimum adhesion, at large, for carcass to tread.

	CYCLE TYRE TREADS			CARCASS	
	1	2	3		1
S-1712	55	—	60	RMA-1X	70
EBR-OE	—	55	—	S-1712	30
EBC 3X	25	25	40	SRF	10
WTR	40	40	—	Ppted $CaCO_3$	60
SRF	—	—	65	Naph. Oil	2
HAF	40	40	40	Cumar	4
China clay	50	50	—	ZnO	4
Naph. Oil	10	10	12	St. acid	1
Mineral rubber	—	—	3	A.O. PBN	1
Cumar	4	4	3	CBS	0.8
ZnO	4	4	4	DPG	0.2
St. acid	1	1	1	Sulfur	2.25
A.O. PBN	0.5	0.5	0.5		
A.O. PBN & DPPD	0.5	0.5	0.5		
P. Wax	0.5	0.5	0.5		
CBS	1.2	1.2	1.2		
TMT	0.3	0.3	0.3		
DPG	0.2	0.2	0.3		
Sulfur	2	2	2.25		
S.G.	1.27	1.26	1.18		1.25
ML4	50	46.5	37	ML4	35
MS	16'0"	16'5"	10'53"	MS	12'36"
Cure @ 162°C	4'	4'	5'	Cure @ 162°C	3'
T.S.	129	123	109	T.S.	176
E.B.	360	375	500	E.B.	650
Mod. 300%	97	92	67	Mod. 300%	34
Hardness	65	66	61	Hardness	45
Flex 2A	62	80	100		—
Flex 2B	12.8	4.0	27.8		—
Abr. loss	4.86	3.96	3.41		—
Air-Ageing @ 70° for 7 days.					
△ E.B.	—22	—21	—18		—11
△ T.S.	— 4.6	— 7.3	— 4		—20
△Hardness	+ 5	+ 6	+ 5		+ 5

CYCLE TUBES

At present, cycle tubes are manufactured by two methods :

(a) Mandrel cure by open steam pressure in a vulcanizer

(b) Watch-case Moulding.

Both these methods call for different types of compounds. Upto the stage of extrusion of green tubes, the steps are common for both the methods. Cycle tube compounds for the mandrel-method, must have excellent extrusion characteristics like fast extrusion speeds, excellent surface finish and adequate resistance to scorch.

The requisites of vulcanisate characteristics are :

(1) High elongation with low modulus.
(2) Very low permanent set.
(3) Excellent air-retention property.
(4) Good age-resistance.
(5) High tear strength.

Synaprene rubbers show excellent air-retention property in comparison with NR.

	Nitrogen Permeability*
Natural rubber	4.10
SBR (23.5% Styrene—37.5 phr oil)	2.68
SBR (23.5 Styrene)	2.56
SBR (43% Styrene)	0.838
Butyl (IIR)	0.063

*In Cu. ft @ STP through 0.001" thickness per sq. ft. per psi pressure difference (Ref. FR-S synthetic rubber and latex facts Vol. 2).

BLACK CYCLE TUBES

					RED
	1	2	3		4
S-1712	100	60	60	RMA-1X	70
S-1513	—	40	—	S-1502	30
RMA 1X	—	—	40	Ppted. $CaCO_3$	80
FEF	60	60	60	Naph. oil	10
Naph. oil	20	20	20	ZnO	4
ZnO	4	4	4	St. acid	1.5
St. acid	1.5	1.5	1.5	A.O. SP	1.5
A.O. DPPD	1	1	1	P. Wax	0.5
A.O. PBN	1	1	1	MBTS	1
P. Wax	1	1	1	TMTD	0.2
MBT	0.7	0.7	0.5	Sulfur	1.3
MBTS	0.5	0.5	0.5	TiO_2 & Color	q.s.
Sulfur	1.4	1.4	1.4		
S.G.	1.14	1.14	1.13		1.25
ML4	30	34	32		35
MS	25'30"	—	—		—
Cure @	10'	10'	10'		8'
152°C					—
T.S.	132	135	153		160
E.B.	650	650	670		625
Mod. 300%	52	62	58		48
Hardness	46	48	48		44
Tear S	39	37	42		—
P. Set %	3.1	5.9	5.9		3.1
Air-Ageing @ 70°C for 7 days					
△ T.S.	— 4	— 3	— 2		—1.1
△ E.B.	—20	—22	—24		—8
△ Hardness	+ 4	+ 5	+ 4		+1

CONVEYOR BELTS

Conveyor belts transport materials at low speed and operate over big pulleys. A typical belt consists of a carcass and covers (top and bottom). The function of the carcass is to carry the load, while the covers protect the carcass from wear and tear, shocks, deleterious effects of solvents, oils, heat, ozone and weathering.

Synaprene rubbers could be advantageously used for conveyor belt cover and friction, skim compounds to meet I.S. Specifications 1891: Grade R and S and B.S.S. 490: Grade M & N. A good heat resistant cover compound could be also developed with Synaprene rubbers. The essential vulcanizate characteristics of cover compounds are :

(a) Excellent abrasion resistance along with high flexibility.
(b) Very good resistance to atmospheric oxygen and heat-ageing.
(c) High tensile and tear strength along with reasonably high co-efficient of friction to prevent slippage under dry as well as wet conditions.

The green compound should have adequate building tack.

Synaprene rubbers surpass natural rubber in abrasion and age-resistance. For maintaining high co-efficient of friction, Synaprene 1500 and 1502 could be selected. Oil-extended grade is not preferred only because of slightly low tear strength. Synaprene 1502 is preferred for covers to be used for conveying food-products.

NOTES ON MIXING : To get the best physicals it is necessary to follow two-step mixing.

(1) A masterbatch of Synaprene 1500, ISAF and Stearic Acid is made and allowed to rest overnight. ISAF should be added to the rubber at tight nip.
(2) Next day, the masterbatch is remasticated on mill for 20 minutes and then the other compounding ingredients are added Refining is done on tight nip four times. Straight mixing gives poor results with tensile-strength as low as 180 kg/cm^2.

CONVEYOR BELT COMPOUNDS
GENERAL PURPOSE

	Cover	Cover	Friction & Skim
DU/471/B	(1)	(2)	(3)
S-1500	100	50	20
RMA 1X	—	50	80
ISAF	40	40	—
SRF	—	—	10
Ppted $CaCO_3$	—	—	60
Pine Tar	5	3	3
Cumar	5	3	3
Zinc Oxide	4	4	4
A.O. PBN	0.8	0.8	0.5
A.O. Ketone-Amine	0.6	0.6	0.5
A.O. ETDQ	0.6	0.6	0.5
St. Acid	2	2	1
CBS	1.2	0.8	0.6
Sulfur	1.8	2.1	2.25
Microwax	1	1	—
S.G.	1.12	1.12	1.12
ML4	56	44	—
MS	21'	18'	—
Cure @ 152°C	20'	15'	15'
T.S.	234	238	174
E.B.	700	715	675
Mod. 300%	62	53	31.5
Hardness	58	60	44
Tear S.	52	54	—
Air-Ageing @ 70°C for 7 days.			
△T.S.	− 2	− 6	−11
△E.B.	−22	−24	−20
△Hardness	+ 4	+ 2	+ 5

TRANSMISSION BELTS

Transmission belts transmit power and operate at high speeds over smaller pulleys in comparison with conveyor belts. Although flat transmission belts and V belts both are grouped under a common heading, the first type calls for high flexibility but total non-strechability to avoid loss of efficiency in power-transmission.

Compounds for V belts should withstand high speed flexing and heat, while those for flat transmission belts should have age resistance.

Flat Transmission Belt Compounds

	Skim	Friction
DU/471/D	(1)	(2)
S-1502	60	20
RMA-1X	40	80
Ppted $CaCO_3$	60	60
Soft clay	100	—
Naph. oil	3	—
Cumar	5	3
ZnO	5	5
St. acid	1.5	1.5
A.O. S.P.	1.5	1.5
P. Wax	1	—
CBS	1.2	0.6
DPG	—	0.2
TMTD	0.2	—
Sulfur	2	2.25
S.G.	1.55	1.24
ML4	55	37
MS	21'18"	17'18"
Cure @ 152°C	10'	10'
T.S.	105	209
E.B.	500	590
Mod. 300%	65	51
Hardness	61	49
Air-Ageing @ 70°C for 7 days		
△ T.S.	—15	— 5
△ E.B.	—18	—10.5
△ Hardness	Nil	+ 3

V-BELT COMPOUNDS*

	Base	Cushion	Skim**	Friction
DU/471/C	1	2	3	4
S-1500	85	70	60	20
RMA 1X	15	30	40	80
SRF	100	60	40	10
Ppted $CaCO_3$	—	—	—	50
Naph. oil	10	5	7	2
Cumar	5	5	5	3
Zinc Oxide	4	4	4	4
St. Acid	2.5	2.5	2	2
A.O. PBN & DPPD	1	1	1	1
A.O. Ketone-Amine	1	1	1	1
CBS	1.4	1	0.8	0.8
TMTD	0.2	—	0.1	—
Sulfur	2	2	2	2.5
S.G.	1.23	1.16	1.10	1.21
ML4	63	44	40	39
MS	21'38"	24'3"	29'3"	24'
Cure @ 152°C	15'	15'	15'	10'
T.S.	158	184	201	183
E.B.	260	475	600	600
Mod. 100%	63.5	26	13.5	20.8
Mod. 300%	—	105	52.5	53
Hardness	75	61	53	51
Tear S.	51.5	57	43	38
Air-ageing @ 70°C for 7 days				
△T.S.	— 2	— 9	—18	—13
△E.B.	—19	—25	—20	—17
△Hardness	Nil	+ 4	+ 2	+ 5
Air-ageing @ 100°C for 3 days				
△T.S.	— 3	—20	—35	—49
△E.B.	—42	—51	—39	—42.5
△Hardness	+ 5	+ 4	+ 5	+ 4

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*V belt compounds could be also used to manufacture automotive fan belts

**Instead of a special skim compound, it is also a practice to use friction stock as a skim coat.

MOULDED GOODS

Synaprene rubbers have many advantages to offer for moulded goods compounds. Some of these are :—

(1) Uniformity in raw polymer properties, curing characteristics and colour.

(2) Resistance of raw stock to mechanical degradation while processing.

(3) Relative freedom from scorch :

Rubber stock may have to pass through intermediate processing operations like extrusion or calendering for preparation of the preform. It is very essential that the stock must not scorch during the preparatory stage, and also at the time of moulding the stock must have sufficient delayed set-up to get a good mould flow during moulding operations. Synaprene rubbers are comparatively scorch-resistant even for highly accelerated stocks to get faster production. Preforming operations by extrusion or calendering for ease of working, faster production and better quality can be resorted to, without fear of stock setting up during these operations.

(4) Storage of preforms or blanks is easier.

(5) For faster production, higher temperatures of moulding can be used without any loss in vulcanizate properties.

(6) No reversion or development of tackiness occurs, even on overcures.

(7) Synaprene rubbers have 13% better heat diffusivity than natural rubber, hence in thicker articles, the time of incubation i.e. time allowance to be made

for heating up of the stock, will be lower in the case of Synaprene compounds and the defects due to back-rinding or chattering will be less.

(8) Synaprene rubbers can be extended with higher quantities of mineral oils to obtain a lower volume cost of a compound.

Synaprene rubbers also offer the following advantages regarding vulcanizate characteristics :

(1) Better resistance to deterioration due to oxygen, heat or weathering.

(2) Better oil resistance than corresponding natural rubber vulcanizates and hence less deterioration due to any accidental contact with lubricating oil or grease.

(3) Better resistance to traces of rubber poisons like copper and manganese and hence better service life of highly mineral-filler loaded vulcanizates.

During moulding, various problems arise and some problems are common for all types of rubbers. To over come these, the following table shows some guide lines :

TABLE 26 : TROUBLE SHOOTING FOR MOULDING

Problem	Cause	Corrective Action
1. Air-Marking or Surface Shyness	Undercure	Increased cure-time or faster cure system.
2. Air Trapping	i) Excessively soft stock	i) Mastication time of polymer should be reduced. Use of stiffer elastomer like Synaprene 1514.
	ii) Insufficient stock in the cavity	
	iii) Improper design of mould	iii) If mould cannot be designed with a parting line at the remote corners, vent holes (less than 0.5 mm dia.) should be provided.
	iv) Improper shape of blank	iv) Use of properly shaped blank and proper placement of blank.
	v) Insufficient moulding pressure	
	vi) Too fast a rate of closing	vi) Slow increase in pressure and proper bumping.

Problem	Cause	Corrective Action
3. Air-trapped beneath surface	i) Air entrapped in the blank	i) Use of extruded blank.
4. Porosity or Sponginess	i) Undercure	
	ii) Moisture in ingredients specially in mineral fillers	ii) Pre-heat the fillers before mixing.
5. Distortion	i) Undercure leading to bulging in the thickest section	
	ii) Use of partially scorched stocks	
	iii) Use of excessive amount of thermo-plastic resins	
6. Short flow or flow cracks	i) Too fast set up of the stock	i) This is unlikely to be the case with Synaprene compounds, but, if observed, accelerator can be slightly reduced.
	ii) Insufficient moulding pressure especially in case of	ii) Design compound with low viscosity if moulding pressure cannot be in-

Problem	Cause	Corrective Action
	stiff stocks	creased. Alternatively preheating the blanks may be sufficient.
	iii) Improper blank design giving excessive spend leading to short and inadequate moulding pressure in the cavity proper	iii) Proper blank design and proper placement of the blanks in the cavity.
7. Delamination or improper knitting	i) Presence of dust, bloom on the blank	i) Blanks should be properly stored and should be used as early as possible to avoid the formation of bloom.
	ii) Excessive use of mould lubricant	ii) Mould lubricants, especially of silicone type, should be very sparingly used on the mould.
	iii) Insufficient tack	iii) Use of tackifying resins like cumar.
8. Backrinding aggravated in case of thick articles	i) Poor thermal diffusivity of the rubber	i) Synaprene rubber have approximately 13% better heat diffusivity than natural rubber and hence less problematic. Use of lower temps of cure. Use

Problem	Cause	Corrective Action
	ii) Excessive mould loading leading to excessive flow and improper closing of the mould.	of delayed action accelerators. Use of better heat conducting fillers like ZnO.
9. Tearing of the article while removing from mould and/or core	i) Lowering of tear strength at higher temperatures	i) Cooling the article before removal from mould and/or core. Two or more cores should be used to maintain desired production. Compounding for high tear strength e.g. a) by use of furnace blacks like ISAF in black compounds and silica-silicate fillers in coloured compounds. b) Use of cumar resin. c) Proper level of sulfur and state of cure will improve tear strength.
	ii) Overcure	ii) Proper adjustment in cure time or level of curatives.

Problem	Cause	Corrective Action
10. Pebbling	i) Improper dispersion of sulfur or use of a carbon masterbatch made at very high temperature (High carbon-gel)	Proper precautions during mixing of the compound.
11. Excessive flash	i) Excessive filling	i) Check the blank weight.
	ii) Improperly shaped pre-form	
	iii) Too soft a stock	iii) Use of Synaprene 1514.
	iv) Too slow a setting period	iv) Increase booster accelerator level.
	v) Too high a curing temperature	v) Lower the temp. or increase the booster accelerator.
12. Thick flash	i) Low moulding pressure	i) High pressure or to switch over to Hydraulic press in place of hand press.
	ii) Too tough a stock	ii) Use Synaprene 1958 or 1513 or decrease mineral filler loading.
	iii) Too fast a setting period	iii) Reduce the level of booster accelerator.

Problem	Cause	Corrective Action
	iv) Too low a curing temperature	iv) Increase the temperature or decrease the booster.
13. Sticking in the cavity	i) Undercure ii) Use of clays or silicates	ii) Use of proper mould lubricant. Use of internal lubricants like low molecular weight polyethylene, or increased levels of stearic acid or paraffinic oils. In case of ebonite compounds use of castor oil or soap.

COMPOUNDS FOR MOULDED GOODS:

In the following series, moulded compounds in various hardness grades are given. Addition of processing resins like cumar in these compounds will enhance the physical properties of the compound without much affecting the hardness. This addition of resin will also improve the flow further and will give better knitting and better gloss on the finished product. Enhanced physical properties will also be obtained if the booster accelrator level is reduced and the compounds are cured for longer time.

These compounds will give products with excellent finish in a mould with polished surface. However, for good retention of gloss it is advisable to use antiozonants of quinoline derivatives, for Synaprene 1712 compounds. Synaprene 1502 will give non-staining type of vulcanizates and Synaprene 1712 will give staining type vulcanizates. Compounds are designed for fast curing with optimum cure time of 7-10 mins @ 152°C. for higher productivity.

SHORE A-2 HARDNESS RANGE 40±5

DU/5970/F	(1)	(2)	(3)	(4)
S-1712	100	100	100	100
SRF	50	60	50	—
HAF	—	—	—	55
China clay	—	25	40	25
Whiting	—	25	40	25
Naph. oil	20	25	25	55
Zinc oxide	4	4	4	3
St. acid	1.0	1.0	1.0	1.0
A.O. PBN	1	1	1	1
P. Wax	1	1	1	1
CBS	1.2	1.2	1.2	1.25
TMTD	0.2	0.2	0.3	0.30
Sulfur	1.6	1.8	1.8	2
S.G. (Actual)	1.05	1.21	1.29	1.25
Cure @ 152°C	10'	10'	10'	10'
T.S.	114	94	80	85
E.B.	575	600	575	450
Mod. 300%	50	42	37	48
Hardness	39	44	44	43
Comp. set%	18.95	33	34	32

SHORE A-2 HARDNESS RANGE 50±5

	(1)	(2)	(3)	(4)
S-1712	100	100	100	100
HAF	—	40	—	—
SRF	50	—	50	40
China clay	—	—	30	60
Whiting	—	60	30	60
Naph. oil	10	—	20	20
Ar. oil	—	30	—	—
Zinc oxide	4	4	4	4
St. acid	1	1	1	1
A.O. PBN	1	1	1	1
P. Wax	1	1	1	1
CBS	1.2	1.5	1.2	1.2
TMTD	0.2	0.2	0.3	0.3
Sulfur	1.6	1.7	1.8	1.8
S.G. (Actual)	1.06	1.33	1.23	1.34
Cure @ 152°C	10'	10'	10'	10'
T.S.	133	116	84	70
E.B.	580	500	510	490
Mod. 300%	61	53	49	41
Hardness	50	51	52	53
Comp. set%	23.9	28.2	29.8	38.3

SHORE A-2 HARDNESS RANGE 60±5

	(1)	(2)	(3)	(4)
S-1712	100	100	100	100
HAF	25	25	60	25
SRF	25	25	—	25
China clay	—	80	--	80
Whiting	—	80	75	120
Naph. oil	3	10	15	20
Zinc Oxide	4	4	3	4
St. acid	1	1	1	1
A.O. PBN	1	1	1	1
P. Wax	1	1	1	1
CBS	1.2	1.2	1.25	1.2
TMTD	0.2	0.2	0.3	0.3
Sulfur	1.6	1.8	2	2
S. G. (Actual)	1.13	1.50	1.33	1.53
Cure @ 152°C	10'	10'	10'	10'
T.S.	174	75	116	56
E.B.	500	450	305	385
Mod. 300%	102	46	71	41
Hardness	58	63	57	62
Comp. set %	17.3	38.8	25	42

SHORE A-2 HARDNESS RANGE 70±5

	(1)	(2)	(3)	(4)	(5)
S-1502	100	—	—	100	—
S-1712	—	100	100	—	100
HAF	55	55	55	55	55
China clay	—	50	50	80	80
Whiting	—	—	50	80	80
Naph. oil	5	5	7	5	10
Cumar	3	3	3	3	3
ZnO	4	4	4	4	4
St. acid	1	1	1	1	1
A.O. PBN	1	1	1	1	1
P. Wax	1	1	1	1	1
CBS	1.2	1.25	1.20	1.2	1.2
TMTD	0.2	0.25	0.30	0.3	0.3
Sulfur	1.8	1.8	1.8	2	2
S.G. (Actual)	1.18	1.33	1.41	1.57	1.57
Cure @ 152°C	10'	10'	10'	10'	10'
T.S.	187	154	110	104	68
E.B.	360	340	320	255	245
Mod. 300%	150	132	104	—	—
Hardness	72	68	65	75	72
Comp. set%	27	37	41	42	46

SHORE A-2 HARDNESS RANGE 80±5

	(1)	(2)	(3)	(4)
S-1502	80	80	90	100
S-1958	20	20	10	—
HAF	60	50	50	50
China clay	50	100	50	100
Whiting	—	—	120	100
Naph. oil	5	5	5	10
Cumar	3	3	3	3
ZnO	4	4	4	4
St. acid	1	1	1	1
A.O. PBN	1	1	1	1
P. Wax	1	1	1	1
CBS	1.2	1.2	1.25	1.2
TMTD	0.2	0.3	0.3	0.4
Sulfur	2.2	2.0	2.2	2.25
S.G. (Actual)	1.26	1.34	1.62	1.65
Cure @ 152°C	10'	10'	10'	10'
T.S.	182	138	86	91
E.B.	275	300	205	275
Mod. 100@	73.5	62	—	39.2
Hardness	83	84	87	79
Comp. set%	36.5	49.6	41	46.8

Brake Cylinder Cup.		**Heat resistant Compound**	
Synaprene 1500	100	Synaprene 1502	100
HAF	62.5	FEF	30
Cumar	5	Pptd. $CaCO_3$	150
Ar. oil	2.5	Cumar	5
Zinc oxide	4	Naph. oil	5
St. acid	2	St. acid	1.5
A.O. Ketone- amine	1	A.O. Ketone-amine	1.5
A.O. PBN & DPPD	1		
P. Wax	1	P. Wax	2
TMTD	0.75	TMTD	0.75
TETD	0.75	TETD	0.75
ZDC	0.30	ZDC	0.30
Sulfur	0.50	Sulfur	0.50
S.G.	1.17	S.G.	1.52
Cure @ 152°C	10'	Cure @ 152°C	15'
T.S.	243	T.S.	62
E.B.	450	E.B.	375
Hardness	67	Hardness	65
Comp. set%	14		
Aged @ 120°C for 70 hrs. in		*Air-aged @ 140°C for 24 hrs.*	
ΔE.B.	—45		Nil
ΔT.S.	— 1		—16
ΔHardness	+ 5		+ 6
Air-aged @ 125°C for 70 hrs. *Brake Fluid*			
Δ T.S.	—29		
Δ E.B.	—30		
Δ Hardness	—11		
Δ V	+ 5.8		

	Shock Absorber Bushing	Suspension Bushing		Grommets
	(1)	(2)	(3)	(4)
Synaprene 1502	50	—	—	—
Synaprene 1712	—	70	70	100
NR	50	30	30	—
HAF	—	30	25	55
FEF	40	—	—	—
Naph. oil	8	15	15	5
Hard clay	—	50	100	50
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	1
A.O. PBN	—	1	1	1
A.O. Ketone-amine	1	—	—	—
A.O. ETDQ	1	—	—	—
P. Wax	—	1	1	1
CBS	1	1.2	1.25	1.25
TMTD	0.1	0.2	0.25	0.25
Sulfur	2.2	1.8	1.9	1.8
S.G.	1.10	1.24	1.37	1.33
Cure @ 152°C	10'	10'	10'	10'
T.S.	188	162	133	154
E.B.	425	510	510	340
Mod. 300%	109	117	60	132
Hardness	58	52	56	66
Comp. set%	27	31	36	37

	Bellows	Steering Wheel Boot	Dust Cover Boot
Synaprene 1712	100	100	100
HAF	40	25	—
SRF	—	—	50
Whiting	60	75	—
Naph. oil	30	15	20
Zinc Oxide	4	4	4
St. acid	1	1	1
A.O. PBN	1	1	1
P. Wax	1	1	1
CBS	1.2	1.2	1.2
TMTD	0.2	0.2	0.2
Sulfur	1.7	1.7	1.6
S.G.	1.33	1.28	1.13
Cure @ 152°C	10'	10'	10'
T.S.	116	130	114
E.B.	500	450	575
Mod. 300%	53	62	50
Hardness	51	54	41
Comp. set%	28.2	28	18.95

AUTOMOTIVE BUMPERS

	1	2	3	4
Synaprene 1514	100	100	80	60
Synaprene 1958	—	—	20	40
HAF	—	50	50	40
FEF	40	—	—	—
Hard clay	60	100	75	100
Ar. oil	30	20	7.5	5.0
Zinc Oxide	3	3	3	3
St. acid	1.5	1.5	1.5	1.5
PBN	1.0	1.0	1.0	1.0
A.O. ETDQ	1.5	1.5	1.5	1.5
P. Wax	1.0	1.0	1.0	1.0
CBS	0.75	0.75	0.6	0.8
MBT & DPG	0.75	0.75	1.0	1.0
Sulfur	1.8	1.8	1.75	1.6
S.G.	1.28	1.41	1.37	1.43
Cure @ 152°C	12'	12'	15'	15'
T.S.	127	125	141	111
E.B.	605	450	290	265
Mod. 300%	49	86	—	—
Hardness	52	67	80	86

	Foot pedal Pads 1	**Gaskets Rubber Fastner** 2	**Ventilator Window Seal** 3	**Water stop** 4
Synaprene 1502	—	—	45	—
Synaprene 1712	70	70	—	50
Synaprene 1958	—	—	10	—
RMA 1X	30	30	45	50
FEF	25	30	30	30
Hard clay	100	—	—	25
Soft clay	—	50	50	—
Ar. oil	—	—	—	10
Naph. oil	15	15	15	—
Cumar	—	—	10	5
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	2
A.O. PBN	1	1	1	1
A.O. ETDQ	—	—	—	1.5
P. Wax	1	1	1	1
CBS	1	1	1	—
MBTS	—	—	—	1.5
TMTD	0.2	0.2	0.1	2.5
Sulfur	1.8	1.8	2.2	0.5
S.G.	1.37	1.21	1.37	1.19
Cure @ 152°C	10'	10'	10'	10'
T.S.	138	139	86	161
E.B.	590	560	475	500
Mod. 300%	56	55	61	71
Hardness	55	53	65	56
Air-aged @ 70°C for 168 hrs.				
△T.S.	—12	—15	—18	—20
△E.B.	—22	—24	—22	—13
△ Hardness	+ 6	+ 4	+ 4	+ 2

	DOOR STOP 1	**BATTERY TRAY** 2
Synaprene 1502	—	80
Synaprene 1712	100	—
Synaprene 1958	—	20
FEF	45	50
Hard clay	120	120
Naph. oil	15	10
Cumar	—	5
Zinc Oxide	4	4
St. acid	1.5	1.5
A.O. PBN	1	1
P. Wax	1	3
CBS	1.2	1.2
TMTD	0.2	0.3
Sulfur	2	2
S.G.	1.45	1.47
Cure @ 152°C	7'	10'
T.S.	61	97
E.B.	325	280
Mod. 300%	56	—
Hardness	58	83
Tear S.	21	40
Air-aged @ 70°C for 70 hrs.		
△ T.S.	+ 3	+ 3
△ E.B.	—18	—16
△ Hardness	+ 3	Nil

	Buffer Spring	Laboratory Bottle Stoppers	Valve Ball*	Stereo Plate
Synaprene 1500	25	—	—	—
Synaprene 1502	—	100	—	100
Synaprene 1712	—	—	100	—
RMA-1X	75	—	—	—
HAF	—	—	55	30
SRF	—	—	—	30
FEF	10	—	—	—
Cal. Silicate	—	30	—	—
Hard clay	—	70	100	—
Barytes	—	—	50	—
Whiting	50	—	—	—
Ar. oil	3	—	—	—
Naph. oil	—	10	10	5
Zinc oxide	10	4	3	4
St. acid	1	1	1.5	1
A.O. PBN	1	—	1	—
A.O. SP.	—	1.5	—	1.5
P. Wax	—	—	1	—
CBS	0.8	—	1.2	1
MBTS	—	1.6	—	—
TMTD	0.2	—	—	0.2
DPG	—	0.4	—	—
DEG	—	2	—	—
Sulfur	2	1.75	2	1.8
S.G.	1.28	1.27	1.61	1.22
Cure @ 152°C	7'	10'	30'	20'
T.S.	193	72	102	175
E.B.	565	650	320	240
Mod. 100%	—	—	—	49
Mod. 300%	44	23	87	—
Hardness	64	57	67	61
Comp. set%	1	38.6	37.7	—

*Valve-Ball compound is used for floats of water storage tanks.

	JAR RINGS	**DROPPER CAPS**
Synaprene 1502	100	50
RMA 1X	—	50
Hard clay	60	75
Act. $CaCO_3$	40	75
P. Oil	5	3
P. Jelly	—	2
Zinc oxide	3.5	10
St. acid	1	1
A.O. SP.	1	1
P. Wax	2	2
MBTS	—	1.5
TMTD	—	0.5
TMTM	0.75	—
Sulfur	2.5	1.5
TiO_2 & Colour	qs	qs
Red Oxide	1	—
S.G.	1.42	1.59
Cure @ 141°C	20'	10'
T.S.	40	78
E.B.	400	425
Mod. 300%	30	52
Hardness	61	64
Tear S.	30	47
Tension set %	19	—
Comp. set %	28	37
Air-aged @ 70°C for 168 hrs.		
△ T.S.	+ 3	—32
△ E.B.	—25	—41
△ Hardness	+ 2	+ 5

	✓ Trolly Wheel (Fork-lifts)	✓ Solid Tyres*	✓ Castor Wheel
Synaprene 1500	50	100	—
Synaprene 1514	—	—	80
Synaprene 1958	—	—	20
RMA 1X	50	—	—
HAF	45	30	60
FEF	—	30	—
Barytes	—	—	100
Hard clay	15	15	200
Ar. oil	10	10	—
Naph. oil	—	—	100
Cumar	—	—	10
P. Jelly	—	—	2
Zinc oxide	3.5	3.5	4
St. acid	2.5	2.5	2
A.O. IPPD	1	—	—
A.O. PBN & DPPD	1	1	1
P. Wax	1	1	1
MBTS	—	—	1
CBS	1.1	1.2	—
DPG	0.2	0.3	—
Sulfur	2.1	2.0	7.5
S.G.	1.17	1.20	1.93
Cure @ 141°C	10'	7'	25'
T.S.	210	180	72
E.B.	500	380	90
Mod. 300%	108	140	—
Hardness	60	68	95
Tear S	66	88	41
Comp. set %	24	47	38
Air-aged @ 70°C for 168 hrs.			
△ T.S.	— 9	— 8	+30
△ E.B.	—24	—38	—37
△ Hardness	+ 2	+ 6	+ 1

*Commercial solid tyres for hand drawn vehicles. The compound can be cheapened by 200-300 parts mineral filler with 10-15 parts oil and 3-4 parts additional sulfur.

RUBBER JOINT RINGS

Rubber Joint Rings are used as sealing or gasket material for jointing all types of pipes like water mains, gas mains and drainage. The pipes may be of concrete, vitrified clay, cast iron, steel, plastics, pitchfibre and asbestos cement.

Indian standard (I.S. 5382-1969) have laid the common specifications for gas mains, water-mains and sewers but these have been divided into two types.

(a) Type 1A, 1B, 1C and 1D : rings of natural or synthetic rubber or both, not resistant to oil or solvent.

(b) Type 2A, 2B, 2C and 2D : rings of synthetic rubber, resistant to oil or solvent.

Synaprene rubbers offer higher safety against scorch, required for pre-extrusion of solid cords. Moreover this higher safety also allows longer time for mould-flow to overcome joint failures and imparts thin flash giving a better finish.

Synaprene rubbers are preferred for low compression set at room temperature and as well as at high temperature. Excellent ageing characteristics could be achieved by using very low sulfur.

JOINT RINGS FOR DRAINAGE

Meeting B. S. S-2494-Part 2-1967

DU/2371	1	2	3	4	5
Synaprene 1502	100	100	100	100	100
SRF	40	50	60	70	80
Naph. oil	15	10	5	5	5
ZnO	4	4	4	4	4
St. acid	1.5	1.5	1.5	1.5	1.5
A.O. SP.	2	2	2	2	2
TMTD	0.75	0.75	0.75	0.75	0.75
Sulfur	0.50	0.50	0.50	0.50	0.50
ZDC	0.50	0.50	0.50	0.50	0.50
TETD	0.75	0.75	0.75	0.75	0.75
S.G.	1.12	1.15	1.18	1.20	1.22
Cure @ 162°C	10'	10'	10'	10'	10'
T.S.	125	153	161	159	150
E.B.	590	550	430	410	330
Mod. 300%	50	75	101	108	129
Hardness	45	52	61	64	67
Comp. set % 25% deflection					
@ RT for 72 hrs.	6.9	8.0	8.3	7.2	7.4
@ 70°C for 72 hrs.	12.9	12	12.3	12.4	12.7
Air-aged @ 70°C for 7 days					
△ T.S.	— 7.4	Nil	+ 6	Nil	— 8
△ E.B.	—18.5	—20	— 5	—23	—16.5
△ Hardness	+ 2	Nil	+ 3	+ 5	+ 1

RAIL PADS

A good example of vibration and shock isolation for better ride and comfort is the use of rail pads on railway sleepers which are being progressively used by our Railways. Rail pads are placed between rails and bearing plates on railway tracks. They are some times called 'Grooved sole plates'. Moulded rail pads are manufactured in three sizes.

The Indian Railways have put down draft specifications on "Grooved sole plates" and to meet these specifications, the following three compounds were developed in our laboratory. The compounds were specially designed to meet the stringent requirements on electrical resistance, crushing test, relaxed modulus, compression set and ageing characteristics.

NOTES ON MIXING AND ITS EFFECT ON ELECTRICAL PROPERTIES :

Reinforcing carbon blacks are essential for every high relaxed modulus but the selection of carbon black, its quantity and dispersion during mixing, are very important from the view point of electrical resistance. By taking large-scale factory trials, we have found that 30-45 phr SRF is a safe level to get electrical resistance of the order of 10^9 ohms-cm. Higher amount of reinforcing furnace blacks bring down electrical resistance very fast because of limitations on dispersing efficiency of mixing mills. Banbury mixings with even 50 phr HAF, gives electrical resistance upto 10^{10} ohms-cm. on rail pads.

To get the best dispersion as well as the highest possible physical properties, a masterbatch of Synaprene 1502 and SRF should be made. Keeping the masterbatch overnight and refining on a tight nip will further improve dispersion.

RAIL PAD COMPOUNDS

DU/4470/A	1	2	3
Synaprene 1502	20	65	60
Synaprene 1958	20	10	20
RMA 1X	60	25	20
SRF	30	45	30
China clay	40	25	40
Naph. Oil	2	2	2
Zinc Oxide	4	4	4
St. acid	2	2	2
A.O. PBN	1.5	1.5	1.5
A.O. IPPD	1.5	1.5	1.5
MBTS	2.7	2.7	2.7
Sulfur	0.33	0.33	0.33
Sulfasan R	2.0	2.0	2.0

Cure:— 20' at 150°C (5 mm thickness rail pad)

	1	2	3	Specs.
T.S.	165	153	143	120 (min.)
E.B.	375	400	390	250 (min.)
100% Relaxed modulus	33.6	31.6	34	30-50
Hardness	70	67	69	65 (min.)
*Comp. set%	26	24	26	30 (max.)
Electrical resistance, Ohms-cm	68X10	22X10	25X10	1X10

Air-aged @ 100°C for 96 hrs.

% T.S. retained	95	90	85	(70)
% E.B. retained	87	80	70	(60)
% Change in modulus	+9	+18	+ 16.8	(+40% Change)
Change in hardness	+2	+ 3.	+ 3	
Crushing curve test	Satis-factory	Satis-factory	Satis-factory	

ALL PROPERTIES WERE EVALUATED ON RAIL PADS

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*Comp set % @ 50% deflection on original @ 100°C for 24 hours.

FLOOR TILES

Rubber floor tiles play an important role in interior decoration as well as in industrial floorings. They offer better accoustic and non-slippery properties and also minimise the floor weight of the building construction. Besides imparting moderate chemical resistance they also give fairly good electrical insulation or if required anti-static properties.

Synaprene rubber floor tiles have the following advantages.

(1) Better heat and abrasion resistance as compared to natural rubber.

(2) Higher mineral filler loading capacity, as tiles are made "dead".

(3) Lesser succeptibility to copper and manganese contaminations and hence a longer service life.

(4) Beautifully coloured tiles can be obtained from Synaprene 1502 at low cost.

FLOOR TILE AND ADHESIVE COMPOUND

	Competetive Grade	Superior Grade	Adhesive*
Synaprene 1502	100.0	75.0	—
Synaprene 1513	—	—	50.0
Synaprene 1958	—	50.0	—
EBC 3X	—	—	50.0
Al. Silicate	—	20.0	—
Cal. Silicate	20.0	—	30.0
Hard clay	250.0	100.0	—
Light MgO	30.0	20.0	—
Pptd. $CaCO_3$	150.0	—	—
Cumar	10.0	10.0	—
Zinc Oxide	10.0	5.0	50.0
St. Acid	1.0	1.0	—
P. Oil	2.0	1.5	—
P. Wax	15.0	—	—
Naph. Oil	—	5.0	—

PF-resin (HNR)*	—	—	50.0
CBS	1.5	1.5	—
DOTG	1.0	0.75	—
TMT	0.25	0.25	—
Sulfur	9.0	3.0	—
NDPA	0.5	0.5	—
A.O. SP.	1.5	1.5	—
TiO_2 & colour	qs	qs	—

*PF Resin HNR is heat non-reactive phenol formaldehyde resin.

(1) The adhesive recipe is mixed on the mill with 10 phr phenolic HNR resin only.

(2) The balance of phenolic resin (40 phr) is dissolved in a small quantity of 'Bentol'†, a mixture of toluene and benzene in the approximate ratio of 70:30 to give a solids content of 30%.

(3) Floors on which rubber tiles are to be fixed should be dry, clean and dirt free. Newly laid wet and damp floors should be avoided. If floor surface is oily or greasy suitable solvent should be used for cleaning.

(4) Laying lines should be marked out preferably starting from the centre of the room, and the tiles should be trimmed to give joints having minimum clearance. If need be a 'wood planer' can be used to square the edges of the tiles.

(5) Floor tile adhesive should be applied on the floor surface as well as on the tile by a soft brush giving a thin coating of the same.

(6) The adhesive is allowed to dry till the solvent has evaporated and the adhesive at is sufficiently tacky.

(7) The adhesive coated tile is then laid on the surface with a little pressure and after covering a small floor area with the tiles a heavy steel roller is passed over several times.

(8) After all the tiles are laid they should be rolled down uniformly atleast once.

† 'Bentol' is a mixture of benzene and toluene.

PENCIL ERASERS

It may be said that the consumption of erasers is a measure of literacy in a country. As the percentage of literacy goes up, the demand for erasers increases. Low mooney rubbers such as Synaprene 1513 are recommended for eraser compounds, but properly compounded Synaprene 1502 can also give excellent results.

The essentials for a good eraser are :

(1) It should be inexpensive.

(2) It should not stain and abrade the paper.

(3) Erasure of the pencil mark should be faster.

Keeping in mind the above characteristics, the following recipe has been designed for pencil erasers. Difficulty in mill mixing will not be encountered if the following procedure is adopted.

(1) First add pptd. $CaCO_3$ & light MgO.

(2) Add white factice.

(3) Avoid cutting the rubber-band during mixing.

Synaprene 1502	100.0
Pptd. $CaCO_3$	60.0
Whiting	200.0
Light MgO	20.0
White factice	325.0
Naph. oil	60.0
P. Jelly	25.0
Zinc Oxide	3.0
St. acid	2.0
MBT	2.0
DPG	2.0
Sulfur	7.0
A.O. SP.	1.0
TiO_2 & colour	qs.

Cure: 15' at 160°C (5 mm thick)

RUBBER TO METAL BONDED MOULDED GOODS

Synaprene rubbers could be bonded easily to metal using the techniques similar to those used for bonding natural rubber to metal. Bondability Indices of Natural rubber and SBR were considered lower than those of acrylonitrile and polychloroprene rubbers. But after the introduction of proprietary special bonding agents, the bondability indices of acrylonitrile, polychloroprene and SBR are considered alike, whereas that of Natural rubber is considered slightly lower.

There are four methods of bonding Synaprene rubbers to metal :

(1) Brass plating and Cadmium plating.
(2) Ebonite bonding.
(3) Isocyanate bonding.
(4) Proprietary special bonding agents like Cyclised rubbers, Halogenated rubbers and Rubber Hydrochloride cements.

1. *Brass plating*: Suitable Synaprene rubber compounds, when vulcanised under pressure in direct contact with brass of suitable composition (Cu 65-70%, Zn 35-30%), give an effective rubber to metal bond. The strength of the bond is of the order of 40 kg/cm^2. The metals which can be electroplated with brass and used for bonding to Synaprene compounds are :

Iron, cast or malleable, Steel (Carbon preferably below 0.5%) Stainless steel, Copper and Copper alloys, Zinc and Zinc alloys, Bronze, Aluminium and its alloys, Tin and Nickel.

The strength of the bond is not seriously affected even upto 100°C and the bond can withstand dynamic or impact stresses.

Synaprene compounds with normal sulphur (2 to 3phr) can be bonded by this method. Sulfurless or low sulfur compounds do not give satisfactory bonds.

The bond strength is affected by the degree of cure. Slow accelerators like ZMBT* give good bond strength at shorter cures while semi-ultra and ultra accelerators give better bond strength on longer cure.

However, overcures will diminish the bond strength. The method of bonding with the help of brass plating has some drawbacks. A special electroplating facility is necessary and very critical controls are required at all stages during the manufacture, to get consistently uniform results as the plating conditions porosity and surface stress of the metal deposit determine the adhesion. Current density, composition of the plating bath and the temperature of the plating bath all affect the bondability of the plated surface. Cadmium plating is also getting popular.

2. *Ebonite Bonding*: Ebonite compounds give satisfactory bonds with metals like iron, steel, zinc and chromium (but not with copper, lead and certain varieties of brass or bronzes) on one hand and with soft rubber compounds on the other hand. Hence a soft rubber compound can be bonded to the metals with the help of an intermediate layer of ebonite compound. At room temperature, a bond strength of about 35 to 50 kg/cm^2 can be obtained. However, the strength of the bond rapidly deteriorates with increase in temperature.

The following precautions will achieve better ebonite bonding :

(a) Long cures are required for curing of the ebonite;

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*ZMBT is found to impart highest bond strength with brass-plating system.

(b) Atleast 3mm thick ebonite layer has to be used;

(c) The ebonite interlayer is brittle and hence likely to crack under sudden stresses, unless protected by a sufficient thickness of soft rubber. Because of these reasons, this method of bonding is not used for small parts and is restricted to applications where the article has a thick rubber section and is intended for normal room temperature use e.g. trolly wheels.

3. *Isocyanate Bonding* : This is by far the most widely used bonding method and gives Synaprene rubber to metal a bond strength of about 70 kg/cm^2. The method of bonding is discussed in details in subsequent pages.

4. *Speciality Bonding Agents*: Cyclised rubber, halogenated rubber and rubber hydrochloride cements are widely used as proprietary bonding agents. For bonding polar rubbers to metal a single coat of primer gives good results on bond-strength. But for non-polar rubbers, two coat systems having a primer coat followed by secondary coat is essential.

(a) *Cyclised rubber cements* : These cements give a bond strength of the order of 30-35 kg/cm^2. However, the cements are thermoplastic and hence the bond strength falls rapidly as the temperature is increased.

(b) *Halogenated rubber cements* : These are used by a two coat method. The first or primer coat consists of a mixture of chlorinated rubber and red lead dispersed in an aromatic solvent. After drying of the first coat, a solution of vulcanising type of polychloroprene compound in aromatic solvent is applied as a second coat.

(c) *Rubber Hydrochloride cements* : This is by far the most satisfactory and popular cement used.

All these cements can be used for bonding rubber to metal using steam, hot water or hot air for vulcanising purpose.

Recently other bonding agents like epoxy resin based cements, Hexamine Resorcinol-Silica (HRH) system and other proprietary chemicals have been developed.

METAL SURFACE PREPARATION : Clean surface is of vital importance in getting a good bond. The first treatment given to the metal part is degreasing to remove oil or grease from the surface of the metal. If the parts are too greasy, they are autoclaved under direct steam followed by vapour degreasing with chlorinated hydrocarbon solvents or solvent treatment with petrol, solvent-naphtha or other aromatic solvents. Steel parts can also be treated with alkali solutions to remove grease.

After this the metal parts are cleaned free of rust scale, dust and other foreign matter by scoring sand or shot blasting, vapour blasting (sand blasting in a jet of water) or simply by wire-brushing, polishing with abrasives or machining depending on the size of the metal part and the equipment available. A chemical method like pickling in acids is also used and sometimes both the methods are employed.

Mild steel parts are pickled in dilute hydrochloric acid and thoroughly rinsed with cold water. Traces of acid are removed by dipping the parts, in 4% ammonia solution and the parts are again thoroughly washed in water. Mild steel parts when treated by this method, get rusted very rapidly, especially in humid atmosphere. Hence they should be used as early as possible for further process.

Other methods of pickling of mild steel parts are, to use 15% phosphoric acid or chromic acid solution. After washing by cold water and drying, these parts can be treated further without any danger of rusting and offer very strong rubber to metal bond.

Stainless steel, Nickel and Monel metals should be pickled in chromate solutions. Aluminium parts should be either anodised or pickled. Brass parts should be pickled in conc. Nitric and Sulphuric acid solutions with ZnO. Galvanised iron should be treated with 15% phosphoric acid @ 70°C for only two minutes. Bronze and copper should be brass-plated.

(1) *Preparation of chromate pickling solution* :

Sodium dichromate	12.5 pbw
Nitric acid (conc.)	22.5 pbw

(2) *Preparation of Conc. acid pickling solution* :

Conc. Nitric acid	100 cc
Conc. Sulfuric acid	100 cc
ZnO	8 gms

The following table summarises the treatment for various metals & alloys.

	Metal	**Treatment**
1.	Mild steel	Pickle in HCl or 15% phosphoric and chromic acid pickle.
2.	Aluminium	Anodizing or pickling in solution
3.	Brass	(1) chromate. Conc. Acid pickle. OR (2) Ammonium persulphate etc.
4.	Galvanised Iron	45% phosphoric acid @ 70°C for 2 minutes.
5.	Magnesium	Chromate pickling for 1-2 minutes @ R.T.
6.	Chrome plated nickel, monel and stainless steel	Chromate pickle.
7.	Copper and Bronze	To be brass-plated.
8.	Zinc	Etch with dil. HCl and carefully neutralise.

METHOD OF ISOCYANATE BONDING

After the metal surface preparation, the metal parts are again given a solvent swipe, before applying the bonding agent to remove any traces of oil. The two coats, the primer and the tie coats based on isocyanate agents are prepared in the following manner and a coat of each is applied to the prepared metal parts.

Primer coat : A thin coat of the following solution:
1 pbw 20% Isocyanate solution
1 pbw 15% solution of chlorinated rubber in toluene.

Tie coat :

A thin coat of 20% Isocyanate solution. The tie coat should be applied about 20 minutes after the application of the primer coat. Half an hour after that the metal parts are ready for further process. Isocyanate bonding agents are very susceptible to moisture and decompose in contact with moisture, water and alcohol. Therefore, if the coated metal parts are not to be used immediately for moulding, then a third very thin coat of the rubber stock which is to be bonded, is applied by dissolving the stock in petroleum solvent, to prevent the effect of atmospheric moisture on the isocyanate bonding agent. Such coated metal parts could be stored for as long as 6 to 8 hours before use.

While using proprietary bonding agents it is a practice to apply a primer coat and then a tie coat.

ANTI-BONDING AGENTS : In order to facilitate the cleaning of metal surface and the removal of excess rubber on the metal parts where bonding is not required, the usual practice is customary to paint the surface with, antibonding solution such as chlorinated rubber in toluene or cellulose acetate in acetone.

MOULDING : In designing of transfer moulds care has to be taken to avoid wiping out of the adhesive by the rubber stock which may flow against metal surface that has been coated with a film of bonding agent. It has been observed that the efficiency of heat transfer through the top plate of transfer mould is less because of the clearance between the plunger and the mould. Hence, the degree of cure attained is less in transfer moulds with consequent increase in compression set and hysteresis characteristics.

For the best results, the rubber stock to be moulded should be fresh and free from any bloom. Moulding temperature should not be above 141°C.

During the manufacture, bond failures may occur and the reasons for such failures could be as follows.

TABLE 28 : RUBBER TO CEMENT FAILURE

Cause	*Corrective action*
1) Precure of rubber stock	1) Use fresh compound, lower down the acceleration level or change accelerator type, keep check on the storage life of compound.
2) Too thin a coat of bonding agent	2) Apply multiple coats.
3) Bloom or migration of ingredients	3) Use compatible ingredients or reblend stock.
4) Low moulding pressure	4) Check mould pressure and signs of leakage. Increase weight of blanks.
5) Contaminations of cement-coated metal parts by oil, grease or dust	5) Check unbonded metal parts for contamination. Avoid overspray.
6) Precure of bonding agent	6) Curing cycle should be made at fast curative levels or use lower moulding temperature.
7) Incorrect moulding cycle	7) Keep check on platen temperature and cure rate of compound.

8) Cement rubber incompatibility	8) Try other bonding agent.

TABLE 29 : CEMENT TO METAL FAILURE**

Cause	*Corrective action*
1) Poor metal surface preparation with oily or powdery residue	1) Keep check on degreasing method or use suitable alternate cleaning method.
2) Too short a time allowed for solvent-evaporation	2) Increase time or temperature between application and moulding.
3) Wiping-off of the bonding agents by the flow of the compound past the metal during moulding	3) Prepare proper blanks, use better primer coat.
4) Precure of bonding agent	4) Keep check on bonding agent & speed up coating process.
5) Trapped air forced through bonding agent film	5) Improve mould ventilation.
6) Destruction by solvents from protective paints and rust preventives applied after bonding	6) Avoid ketone based paints and preventives. Avoid dissimilar metals in abrasive cleaning.

**Cement to metal failures are usually marked by a left over clean metal surface.

Synaprene 1500 and 1502 are preferred when high resilience is required in the products. Synaprene 1712 is not considered to be so suitable for this application because of any likely migration of oils to the bonding layer during service. Where damping characteristics are desired e.g. impact bumpers and vibration dampers, Synaprene 1513 & 1514 are preferred.

	Low set compound for Bonding	**Auto engine mount**
Synaprene-1500	100	50
RMA-1X	—	50
HAF	30	—
FEF	30	40
Ar. oil	—	7
Naph. oil	2.5	—
Cumar	2.5	7
Zinc oxide	3.5	10
St. acid	2.5	2
A.O. ETDQ	1.5	1.5
A.O. PBN & DPPD	1	1
P. Wax	1	1
MBTS	1.5	1
TMTD	2.5	—
Sulfur	0.5	2.25
S.G.	1.17	1.14
Cure 141°C	10'	30'
T.S.	220	180
E.B.	350	600
Hardness	65	49
Comp. set%	7	—

VARIOUS HARDNESS COMPOUNDS FOR METAL BONDINGS

	(1)	(2)	(3)	(4)
Synaprene-1500	50	25	70	50
RMA-1X	50	75	30	50
ISAF	30	—	—	—
HAF	—	—	30	50
FEF	—	30	30	—
Pptd $CaCO_3$	—	40	—	—
Ar. oil	4	7.5	2.5	4
Naph. oil	4	7.5	2.5	4
Cumar	4	7.5	2.5	4
Zinc oxide	3.5	3.5	3.5	3.5
St. acid	2	2	2	2
A.O. ETDQ	1.5	1.5	1.5	1.5
A.O. PBN & DPPD	1	1	1	1
P. Wax	1	1	1	1
MBTS	1	0.8	1.25	1
TMTD	—	0.1	—	—
Sulfur	2.25	2.4	2.1	2.2
S.G.	1.09	1.23	1.16	1.14
Cure 141°C	30'	30'	30'	30'
T.S.	238	192	203	237
E.B.	700	550	470	580
Hardness	52	58	62	61

Note: For thick rubber section, the zinc oxide level should be increased (10-50 phr depending on the thickness of the rubber section.

EXTRUDED MECHANICAL GOODS

Synaprene rubbers offer many advantages in this field of application. Their uniformity, freedom from foreign particles, like dust or bark; scorch-resistance; resistance to sagging during storage or cure and the possibility of the reworkability of the scrap after repeated working are the prime advantages.

Among the Synaprene rubbers, Synaprene 1513 and 1514 have best extrusion characteristics and give extrudates with excellent surface finish. The higher green strength of Synaprene 1513 and 1514 permits trouble free feeding of the extruder even with a highly extended compound.

To get high extrusion rates it is advisable to use a mixed loading of the carbon black FEF and Clay. Higher the green strength of the compound, higher is the extrusion rate. With such mixed loadings, even at the low level of the carbon black, it is possible to get smooth extrudates with low die swell.

For good extrusion rate and finish, it is preferable to use naphthenic oils to aromatic oils. Even at high levels of loading, naphthenic oils give a very easy processing stock. Paraffinic oils will give very fast extrusion rate and best surface finish, but these can be used only to a limited extent because of their limited compatibility with rubber and their adverse effects on physicals.

Some production problems, which are common to compounds from all elastomers, are discussed below.

TROUBLES AT THE EXTRUSION STAGE

(1) Porosity in the raw extrudate : This occurs when the back pressure is too inadequate to expel the air in the stock. This may be due to i) too soft stock or ii)

insufficient feed rate due to screw "biting off" the feeding strip or stock sticking to the screw. In the latter case a light dusting with talc of the feed strips helps to overcome- the problem, iii) use of too large a die on a small machine. As a rough guide, the total cross sectional area of the solid portion of the extrudate should not be more than 1/4th of the cross-sectional area of the barrel.

(2) *Poor Knitting* : This defect is found while extruding tubular sections from stiff compounds. The defect may not become apparent at green stage, but the vulcanised product easily tears off along these faulty lines. This defect can be over come i) by increasing the distance between the die and the spider, by using a longer pin and an extension piece; ii) by use of resins, like Synar 240 or cumar or iii) by use of a slightly warm barrel 40-45°C. In case of soft compounds, increase in back pressure at the die will help.

(3) *Torn edges* : This is due to low green strength because of insufficient loading of reinforcing materials. Loading with mineral fillers, addition of tackifying resins like Synar 240, cumar or alkyphenol formadehyde resin also helps remove this defect.

(4) Rough surfaces : They are due to i) improper mastication of natural rubber; ii) improper blending of two polymers; iii) presence of large aggregates of ingredients remaining undispersed; iv) presence of scorched particles in the feed stock or the stock scorching in the extruder barrel or in a dead zone aroung the die, and v) due to low die temp. Scorching difficulties will be less with Synaprene compounds. However, it is always advisable to refine the scrap before adding it to a fresh batch to avoid any contamination of the scrap by foreign particles of sand etc.

TROUBLES OBSERVED AFTER CURE

(1) *Porosity* : This is generally due to slow steam pressure build-up resulting in slower set up of the stock in open steam cure. Presence of excessive moisture in the mineral fillers can also cause such trouble.

(2) *Steam marks*: If a water trough is being used for cooling of the stock, it is advisable to allow the extrudate to dry thoroughly before charging into the vulcaniser. It is also advisable to use dry steam and fit steam traps to avoid accumulation of condensed water near the rubber article during cure. With dry dusting of the extrudate, this defect is seldom encountered.

(3) *Rough surface* : All natural rubber soft compounds are generally prone to this defect. If the compound is not fast setting enough or if the steam pressure build-up is too slow, the particles of the supporting filler e.g. talc get embedded into the article and after cleaning, form pit-marks. It is advisable to use a dry talc lightly loaded into the tray, as the supporting medium.

(4) *Sagging or collapsing* : When Synaprene rubber are blended with natural rubber, the problem of sagging during vulcanisation is not acute. Increasing of secondary accelerator or booster sagging is controlled. For extrusion with very low hardness stocks, Brown factice helps prevent sagging. Even special rubbers like S-1009 (partially cross-linked hot SBR grade) or superior processing-NR (SP Rubber) can be used to solve this problem.

	✓ Trunk Lid Seal	✓ Door Seal	✓ Weather Strip	✓ Filler Cord
	1	2	3	4
Synaprene-1502	60	50	50	—
Synaprene-1513/1514	—	—	—	70
NR	40	50	50	30
FEF	20	30	25	30
Soft clay	30	—	60	200
Whiting	30	40	60	200
Naph oil	20	20	20	40
Br. Factice	15	20	15	10
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	1.5
CBS	1.2	1.2	1.2	1.30
TMTD	0.2	—	0.2	0.30
DPG	0.2	0.4	—	—
Sulfur	1.8	2.2	2.0	2.2
A.O. SP.	1	1	1	1
P. Wax	1	1	1	1
S.G.	1.24	1.18	1.35	1.75
Cure @ 152°C.	8'	10'	8'	8'
T.S.	124	138	92	39
E.B.	575	600	425	300
Mod. 300%	51	62	81	39
Hardness	45	49	55	67

	'Q' Channel	Refrigerator Gasket	Beading	Water Tubing
	1	2	3	4
Synaprene-1502	—	50	—	—
Synaprene-1712	70	—	80	100
NR	30	50	20	—
FEF	30	—	—	20
China clay	100	40	150	200
Ppted $CaCO_3$	20	60	—	40
Naph. Oil	20	15	30	—
Paraffinic oil	—	—	—	25
Cumar	3	3	2	5
Br. Factice	10	15	20	—
Zinc oxide	4	4	4	4
St. acid	1.5	1.0	2	1
CBS	1.0	1.25	1.4	1.2
DPG	0.5	0.40	0.2	0.3
TMTD	—	—	0.2	0.3
Sulfur	2.0	2.0	2.2	2.5
A.O. SP.	1	1	1	—
PBN	—	—	—	1
P. Wax	1	1	2	1
TiO_2 & Colour	—	qs	qs	—
S.G.	1.36	1.33	1.41	1.61
Cure @ 152°C	10'	10'	10'	15'
T.S.	85	91	78	61
E.B.	550	560	500	600
Mod. 300%	58	61	63	42
Hardness	52	55	60	68

LABORATORY TUBING

	✓ High Grade Tubing	✓ Commercial Tubing	✓ Transluscent Tubing
Synaprene-1502	50	40	100
RMA-1X	50	40	—
Red Reclaim	—	40	—
Hydrated Silica	—	—	40
Hard clay	30	—	—
Whiting	60	160	—
Pptd. $CaCO_3$	60	—	—
Naph. oil	15	10	—
P. jelly	—	5	5
Brown factice	20	20	—
Zinc oxide	4	5	—
St. acid	1.5	1.5	0.5
A.O. SP.	1	1	1.5
P. wax	1	2	—
CBS	—	1.4	—
ZMBT	1.2	—	1
TMTD	—	0.3	—
DPG	0.4	—	0.4
DEG	—	—	2
Sulfur	2.2	2.2	2.4
TiO_2	qs	2.5	—
Colour	qs	qs	—
S.G.	1.54	1.47	1.11
Cure @ 152°C	7'	7'	15'
T.S.	76	44	97
E.B.	590	490	600
Hardness	53	53	62

DOMESTIC GAS TUBING

	1	2	3
Synaprene-1502 ✓	50	100	50
RMA-1X	50	—	—
CR	—	—	50
Hard clay	75	75	75
Light $MgCO_3$	—	—	3
Pptd. $CaCO_3$	75	75	75
Naph. oil	5	10	10
Zinc oxide	4	4	5
St. acid	1.5	1.5	1
A.O. SP.	0.5	0.5	0.5
A.O. ETDQ	1.0	1.0	1.0
P. wax	2	2	2
MBTS	1.5	1.5	—
TMTD	0.25	0.25	1.2
DOTG	—	—	1.2
Sulfur	1.75	1.75	1.5
TiO_2 & Colour	qs	qs	qs
S.G.	1.50	1.50	1.55
Cure @ 152°C	20'	20'	20'
T.S.	117	121	83
E.B.	525	575	400
Mod. 300%	—	—	52
Hardness	63	67	65

NOTE: 1) Natural rubber is included to increase the kink resistance.

2) Only dark shades of colour are possible because of staining nature of the antiozonant.

3) Brown Factice upto 20 parts can be added to improve further the extrusion characteristics.

4) Polychloroprene & Synaprene blends offer advantage of controlled inflammability.

EXTRUDED RUBBER SECTIONS OF DIFFERENT HARDNESS (BLACK)

	1	2	3	4	5	6
S-1502	—	—	—	—	50	—
S-1514	80	—	40	—	—	—
S-1712	—	90	—	50	—	70
RMA	20	10	60	50	50	30
FEF	20	20	20	20	35	35
Hard clay	—	—	40	130	120	150
Whiting	200	250	40	—	—	50
Naph. oil	60	60	25	20	25	35
Brown factice	20	20	20	—	15	15
Zinc oxide	5	5	4	4	5	4
St. acid	2	2.5	1.5	1.5	2	1.5
A.O. SP	1	—	1	—	1	—
PBN	—	1	—	1	—	1
P. wax	1.5	1.5	1.5	3	2	1.5
CBS	1.5	1.5	1.2	1.5	1.5	1.35
DPG	0.25	0.25	—	—	—	—
TMTD	0.25	0.25	0.3	0.3	0.4	0.35
Sulfur	1.8	1.7	2.2	2	2.2	2.0
S.G.	1.48	1.54	1.26	1.44	1.38	1.50
Cure @ 152°C	7'	7'	10'	7'	7'	10'
T.S.	31	31	101	108	114	66
E.B.	430	540	410	560	390	315
Hardness	49	43	54	53	68	64

NOTE: Compounds with Synaprene 1712 are staining types. Die swell of these compounds if properly mixed is very low.

Part of naphthenic oil, can advantageously be replaced by paraffinic oil for better extrusion characteristics.

WIRE & CABLE

A cable is a thin walled extruded article. It is very essential that the elastomer used for the compound is free from objectionable foreign particles like sand or bark. The presence of such impurities in the compound necessitates frequent shutdowns of the extruder for cleaning up, due to the clogging of such particles at the die-orifice. The quality of the finished cable is also impaired and electrical faults develop at the spots where such particles occur in the product. The plasticity of the compound has to be controlled within narrow limits to get consistent dimensional uniformity. For good dimensional stability, the compounds must have excellent scorch resistance and should exhibit no tendency to sag during storage or cure.

SYNAPRENE RUBBERS OFFER MANY ADVANTAGES :

The rubbers are uniform in quality and free from foreign impurities. They being resistant to mechanical breakdown, the plasticity control is easy. The compounds exhibit excellent scorch resistance and being less thermoplastic than natural rubber, the extrudates exhibit less tendency to deshape during storage or cure.

Where there is no positive take off for the cable, the cable extrudes due to the frictional drag of the extruding rubber compound. Because of greater frictional drag of Synaprene compound at the orifice, cable extrusion rate will be faster with Synaprene compounds.

Cables are expected to give a long service life and therefore rubber compound must have a very good resistance to ageing. Synaprene rubber vulcanizates exhibit superior age resistance compared to that of natural rubber compounds. Synaprene 1514 is an ideal Synaprene rubber for this application. In addition to all the common advantages of other Synaprene rubbers Synaprene 1514 offers the specific advantage of excellent extrusion characteristics (hence better finish) and enhanced age resistance due to its lower molar unsaturation (Natural rubber: Synaprene 1514: :100:60)

For white sheathing compounds the pale consistent colour of Synaprene 1502 and Synaprene 1514 will mean whiter products with less loadings of whitening pigments like titanium dioxide or lithopone, and a uniform colour in the product.

Specification IS 434 allows the use of Synaprene rubbers in any proportion in sheathing compounds.

Synaprene 1502 and Synaprene 1514 have excellent electrical properties and can be used in insulation compounds for low voltage cable (250/440V).

Especially on copper conductors, the inherently high resistance of Synaprene rubbers to copper poisoning is a great advantage. In fact a copper salt, copper diethyl dithiocarbamate, is used as accelerator in Synaprene compounds. Compounds from both rubbers show very low water absorption (less than 1.5 mg/cm^2 after 7 days immersion in water). One of the main advantages of Synaprene rubbers is the low water absorption characteristics which are retained even on prolonged ageing, in contrast to natural rubber compounds which exhibit pronounced water-absorption on ageing and consequent deterioration in electrical insulation capacity.

CABLE COMPOUNDS FOR CV* CURE

	Insulation		Sheathing	
	1	2	3	4
S-1514	30	—	—	100
S-1502	—	30	50	—
RMA-1X	70	70	50	—
Hard clay	40	90	50	80
Talc (1st quality)	40	20	50	20
Zinc oxide	15	15	15	15
Act. $CaCO_3$	60	40	40	25
Cumar	7	2	2	3
Naph. oil	3	2	3	5
St. acid	0.75	1	1	1
Antioxidant DNP	0.5	—	—	—
A.O. PBN	1.0	—	—	—
A.O. SP	—	1	1	1
P. wax	4	3	3	3
CBS	—	—	1	—
MBTS	1.25	—	—	2.5
MBT & DPG	—	1.5	—	—
TMTD	2.5	—	0.22	2.5
TETD	—	0.4	—	—
ZDC	—	—	0.22	—
Sulfur	0.3	0.75	0.95	0.3
TiO_2	—	10	10	10
Blue colour batch	—	qs	qs	qs
S.G.	1.51	1.59	1.58	1.53
Cure @ 141°C	10'	10'	10'	7'
T.S.	126	121	120	119
E.B.	450	450	570	625
Hardness	65	68	66	66
Aged 120 hrs at 80°C in air				
△ T.S.	— 8	—17	—12	—20
△ E.B.	—10	—11	—12	—20
△ Hardness	— 3	+ 3	+ 2	+ 1

*Continuous Vulcanization.

SYNAPRENE CABLE SHEATHING COMPOUNDS FOR PAN CURED CABLES

	1	2	3
Synaprene-1514	100	100	—
Synaprene-1502	—	—	100
Hard clay	90	60	80
Talc (1st Quality)	—	60	40
Zinc oxide	15	15	15
Act. $CaCO_3$	25	20	20
Cumar	10	5	5
Naph. oil	10	10	10
St. acid	2	1	1
A.O. SP.	1	1	1
P. wax	3	3	3
MBTS	2.5	—	—
CBS	—	1.5	1.2
TMTD	0.5	0.25	—
ZDC	—	—	0.4
Sulfur	1.0	1.5	1.4
TiO_2	10	10	10
Colour	qs	qs	qs
S.G.	1.50	1.54	1.52
Cure at 141°C	30'	30'	30'
T.S.	124	99	89
E.B.	775	725	830
Hardness	58	60	59
Aged 120 *hrs* @ 80°C *in air.*			
△ T.S.	+2	— 5	— 5
△ E.B.	—14	—19	—15

EVALUATION OF CURE SYSTEMS FOR PAN CURED SYNAPRENE CABLE

Base recipe

Synaprene	100	Naph. oil	10
Hard clay	50	Cumar resin	5
Talc (1st quality)	50	St. acid	1
Act. $CaCO_3$	20	A.O. SP	1
Zinc oxide	15	Paraffin wax	3
TiO_2	10	Curatives	as below

S.G. 1.49

MBTS	1.0	1.8	—	—
CBS	1.0	—	1.5	1.2
TMTD	—	0.3	0.25	—
ZDC	1.0	—	—	0.4
Sulfur	1.2	1.4	1.5	1.4
Cure at 141°C	30'	45'	30'	30'
T.S.	95	98	104	100
E.B.	775	825	810	800
Hardness	58	59	60	59
Permanent set	16	16	17	18
Aged 120 hours at 80°C in air				
△ T.S.	— 5	— 3	— 7	— 5
△ E.B.	—10	—12	—14	—13
ZMBT	4	—	—	—
MBT & DPG	—	2	1.8	1.5
TMTD	0.15	—	0.8	0.4
Sulfur	1.25	1.25	0.75	1.2
Cure @ 141°C	45'	45'	30'	30'
△ T.S.	83	100	96	96
△ E.B.	950	925	750	850
△ Hardness	58	59	62	60
Permanent set %	15	14	13	9
Aged 120 hours at 80°C in air				
△ T.S.	— 4	— 7	— 1	—11
△ E.B.	—16	+ 14	— 7	—12

CABLE FILLERS

Butyl reclaim compounds without curatives are preferred as cable-fillers for heavy duty cables. The construction of multicore insulations for such cables leave voids and gaps and to fill it up, cable-fillers or 'Inner sheath' (as per I.S. 1545 part I-1964) materials containing unvulcanized rubber or thermoplastics could be used to minimise 'Corona resistance' and give circular shape too.

For multicore cables, the individual cores are laid up and then surrounded by common covering applied either by extrusion or wrapping with a 'Filler' or 'Inner sheath' material. A proofed or plastic tape may be applied over the common covering. While using a wrapped common covering, the circular shape of a cable should be ensured.

Synaprene 1513, when properly compounded, offers an excellent substitute for butyl reclaim compounds. In blends with S-1958 the compound offers the following advantages.

(1) Excellent age resistance and resistance to metal poisons found in the cheap mineral fillers used, even in unvulcanized state.

(2) Excellent extrusion characteristics even when very highly loaded.

(3) The compound can be conveniently extruded on the plastics extruder.

Typical formulations are given on page 174

✓ CABLE FILLER COMPOUNDS

DU / 4371	1	2
S-1513	—	70
S-1500	70	—
S-1958	30	30
SRF	50	50
Whiting	275	275
Talc	150	150
DBP	5	5
Naph. oil	10	10
St. acid	3	3
P. wax	7	7
S.G. (Actual)	1.69	1.69

Mooney viscosity at 100°C with small rotor.

after 5'	79.5	60.5
10'	77	58
15'	75.5	57.5
20'	75	57.5
Rate of extrusion on 1½" extruder at 50 rpm. cms/min. (0.75 cms diameter solid rods)	326	478
Electrical resistance ohms/ 1.8 mm thickness.	1.4×10^{10}	1.9×10^{10}

HOSES

Hoses vary widely in range of types, sizes and applications.

Hose-structure consists of three parts :

(1) Tube or Lining : Its function is to convey the material, mainly fluids. Generally tube is extruded for hoses upto 8 cm. diameter and for hoses of greater dimension it is built-up from calendered sheets. Tube stock must have good extrusion characteristics, sufficient green tack for building up operations and good green strength in cases where hose is braided vertically without mandrels.

(2) Carcass : It gives the strength to the hose against rupture due to the pressure or suction of the fluid being conveyed. In our country wrapped ply or braided construction for carcass is common. The number of plies depend upon the desired maximum pressure a hose is required to withstand.

The bursting pressure in kg/cm^2 can be approximately calculated for wrapped-ply construction (Hoop force method) as follow :

$$\text{Bursting Pressure} = \frac{2.26 \times S \times N}{D}$$

where; S = Fabric tensile
N = Number of plies
D = Mean ply diameter

For braided hose, & knit type reinforcement the bursting pressure could be also calculated.

For details refer Appendix.

For suction hoses it is customary to use additional wire reinforcemnts. This prevents collapse of the hose during use.

(3) Cover :- It protects the carcass from the external influence during the service and storage. The cover is applied on to the carcass by cross extrusion or by hand. Cover compounds are designed for slightly lower hardness than the tube compounds and should have good tack and green strength.

Uniformity and freedom of the rubber from extraneous impurities, scorch safety of the compounds, good age and weather resistance and overall physicals of the vulcanizates make Synaprene rubbers highly suitable for this field.

Synaprene 1500, 1514 and 1712 are more advantageously used in this application. High loading of mineral fillers is common in these compounds. Synaprene 1712 gives lower viscosity compounds and lower vulcanized hardness compounds at equivalent loading making the fabrication easy and giving a more flexible hose. It has been found that tensile strength below 150 kg/cm^2 are obtained as best economics if based on 1712-HAF-Clay Oil compounds. Where a high green strength is required, e.g. in a hose tube to be braided on vertical machine, Synaprene 1514 is more, suitable. Synarene 1712 in blend with Synaprene 1958 can also be used. Synaprene rubbers are more resistant to swelling by oils than natural rubber. Hence, Synaprene air hoses are less susceptible to damage by oil mist in compressed air.

A hose consisting of tube, carcass and cover has to function as one composite unit and adhesion between the three components is vital. Adhesion in the finished hose does not depend on the initial green tack only; it also depends on the viscosity of the compound, pressure applied during cure and the cure-characteristics of the compound. A delayed onset of cure gives better results.

Synaprene tube and cover compounds containing tackifying resins have adequate building tack. Replacement of a part of the polymer (20-30%) by natural rubber also gives satisfactory tack. The following proportions of these polymers in the various components of hose compounds can be used. Of the two, system B is more practicable.

SBR: NR PROPORTION

	SYSTEM A	SYSTEM B
Tube	80 : 20	100 : 0
Friction	20 : 80	0 : 100
Cover	80 : 20	100 : 0

WATER DELIVERY HOSES

	Tube		Cover Abrasion Resistant	Cover Normal
Synaprene-1712	60	60	60	95
RMA-1X	20	20	20	—
WTR	40	40	40	10
HAF	—	—	—	10
FEF	20	30	40	—
Hard clay	200	150	120	275
Whiting	100	100	60	75
Naph. oil	25	25	25	—
Ar. oil	—	—	—	25
Zinc oxide	4	4	4	4
St. acid	2	2	2	2
A.O. PBN	1.5	1.5	1.5	1
P. wax	1	1	1	1
CBS	1	1	1	1
TMTD	0.1	0.1	0.1	0.1
Sulfur	2.5	2.4	2.2	1.65
S.G.	1.69	1.63	1.53	1.77
Cure @ 152°C	30'	30'	30'	30'
T.S.	49	55	72	54
E.B.	310	300	360	600
Hardness	72	73	68	69

	BRAIDED WATER HOSE		HIGH PRESSURE BRAIDED SPRAY HOSE	
	High pressure	Low pressure	Tube	Cover
Synaprene-1500	—	—	40	—
Synaprene-1712	67.5	67.5	20	60
Synaprene-1958	12.5	12.5	—	—
RMA-1X	20	20	20	30
WTR	—	—	40	20
HAF	60	50	40	40
Hard clay	175	240	120	120
Ar. oil	—	—	10	10
Naph. oil	8	8	—	—
Cumar	6	8	—	—
Zinc oxide	3.5	3.5	4	4
St. acid	2	2	2	2
A.O. PBN	1	1	1	1
P. Wax	0.5	0.5	1	1
CBS	1	1	0.9	0.9
TMTD	0.1	0.1	0.1	0.1
Sulfur	1.75	1.75	2	2
S.G.	1.58	1.68	1.44	1.44
Cure @ 152°C	30'	30'	20'	20'
T.S.	86	60	94	96
E.B.	405	450	—	—
Hardness	74	74	69	63

✓	WELDING HOSE		Vacuum Brake Hose	Feed Pipe for Locomotive
	Tube	Cover		
Synaprene-1500	—	—	50	80
Synaprene-1712	80	80	—	—
RMA-IX	20	20	50	20
HAF	—	45	—	—
FEF	40	—	3	20
Hard clay	220	150	—	80
Whiting	—	—	80	—
Ar. oil	—	12.5	—	—
Naph. oil	—	—	3	—
Bitumen	20	10	—	—
Cumar	7	5	—	1
Zinc oxide	4	4	4	4
St. acid	2	2	1	1
A.O. PBN	1	1	0.5	1
P. Wax	2	1	—	—
CBS	1.5	1.4	0.8	1.5
TMTD	—	0.2	—	—
DPG	0.2	—	—	—
Sulfur	2.25	2.2	2	2
S.G.	1.66	1.55	1.37	1.47
Cure @ 152°C	10'	10'	15'	20'
T.S.	84	92	134	146
E.B.	450	490	715	475
Hardness	74	67	54	68
Aged @ 70°C for 150 hrs.				
△ T.S.	—	—	+ 1	—12
△ E.B.	—	—	—40	—24
△ Hardness	—	—	+ 4	+ 5
Aged @ 121°C for 2 hrs in steam.	—	—	—	no tackiness or cracks.

	RADIATOR HOSE		BOILER WASH OUT HOSE
	1	2	3
Synaprene-1712	100	50	80
RMA-IX	—	—	20
WTR	—	100	—
SRF	100	25	—
FEF	—	—	30
Hard clay	30	50	150
Whiting	30	50	—
Ar. oil	—	—	5
Naph. oil	25/35	5	—
Bitumen	10	5	—
Cumar	—	—	5
Zinc oxide	3	3	4
St. acid	1	1	2
A.O. PBN	1	1	1
P. Wax	1	1	1
CBS	0.8	0.6	1.2
TMTD	0.2	0.2	—
DPG	—	—	0.3
Sulfur	2	2.5	1.7
S.G.	1.36	1.42	1.53
Cure @ 152°C	20'	20'	30'
T.S.	83	59	89
E.B.	400	300	460
Mod. 300%	66	59	—
Hardness	57	60	70
Airaged @ 70°C for 7 days:			
△ T.S.	— 7.2	— 1.7	— 1
△ E.B.	—20	—20	—20
△ Hardness	+ 7	+10	—

SPONGE RUBBER

Sponge rubber generally means rubber with communicating cells or open cells. Sponge rubber is manufactured by partially loading the mould with rubber stock containing a gas release agent and curing in press or in open steam. In India, generally, dinitrosopentamethylene tetramine (DPT) type of blowing agents are used. The specific gravity of the product depends on the degree of loading.

To get a product with low specific gravity raw stocks must have very low viscosity. For this purpose, natural rubber has to be peptised by prolonged mastication. Synaprene rubbers, inherently, have a low viscosity which can be further reduced by proper loading of softeners. Very high loading of oils (even 80 phr) are possible in Synaprene rubbers without making the stock sticky and difficult to handle.

To get good sponge, careful balance in curing characteristics is required. A delayed action set up, to allow the gas liberated to inflate the stock fully before any set up occurs, followed by a rapid cure rate to avoid the collapse of the sponge is necessary. It is very easy to achieve above balance characteristics in Synaprene rubbers.

Preforms in moulded sponge products should be liberally dusted with talc to avoid any air entrapment. The mould should have air vents at proper places. It may sometimes be necessary to place a piece of talc dusted fabric below the top-plate to allow air to escape through the fabric. Mould closing pressure must not be high and should be just sufficient to ensure proper contact of the hot plates with the mould.

Addition of 10-15 phr sponge crumbs are found useful in giving uniform expansion to the product. In open steam cure, if a low steam pressure is used in the beginning followed by high steam pressure, a product with low density is obtained. In hot air cures, it is preferable to cure with an air pressure of 25-30 psi. to get a good skin on the products.

To get a uniform dispersion of blowing agent it is advisable to make a dispersion of the blowing agent in the oil. Aging the stock atleast for 12 hours after the addition of the blowing agent and refining before use, is recommended.

Low Mooney SBR-like Synaprere 1513 is preferred for sponge compounds, as it helps in faster mixing and uniform blowing due to less 'nervy' stocks.

✓	**Black Sponge** 1	**Coloured Sponge** 2	**Sponge Armrest** 3	**Padding for door handle** 4
Synaprene-1502	—	—	100	100
Synaprene-1513	100	100	—	—
FEF	—	—	40	30
SRF	30	—	—	—
Cal. Silicate	—	15	—	—
Whiting	80	80	100	100
Naph. oil	70	70	60	75
Zinc oxide	5	5	4	4
St. acid	2	2	3.5	4
A.O. SP	—	1	1	1
A.O. PBN	1	—	—	—
P. Wax	—	—	3	3
MBTS	3	3	—	—
CBS	—	—	1.5	1.5
Sulfur	4.5	4.5	3	3
$NaHCO_3$	14	14	—	—
DPT	3	3	3	3
Retarder TSA	—	—	0.5	0.5
Starch	2.5	2.5	—	—
TiO_2 & Colour	—	qs	—	—
Cure @ 152°C*.	25'	25'	15'	20'
Mold loading (vol.)	30%	35%	50%	33%
Blown S.G.	0.37	0.29	0.73	0.44
Stress for 50% compression kg/cm^2	—	—	2.0	0.44
Stress for 25% compression kg/cm^2	0.27	0.11	—	—

* For compound No. 1, 2, the cure time is for 1" thickness, but for compound No. 3 and 4 the thickness is 1/2".

NOTE: To get low specific gravity (Blown), 4 phr oleic acid and 15 phr $NaHCO_3$, should used for compound No. 3 and 4.

EXTRUDED SPONGE CHANNELS

	1	2	3	4	5
S-1502	75	—	—	—	—
S-1514	—	—	100	—	—
S-1712	—	100	—	100	75
RMA-1X	25	—	—	—	15
WTR	—	—	—	—	20
FEF	30	15	15	50	25
Soft clay	20	15	100	—	80
Whiting	20	100	60	25	80
Ar. oil	—	—	—	30	—
Naph. oil	40	25	50	—	30
Cumar	—	—	—	5	—
Brown factice	20	15	15	—	15
Zinc oxide	5	4	4	3.5	4
St. acid	4	5	5	3	5
A.O. SP.	1.5	1.5	1.5	—	—
A.O. PBN	—	—	—	1.5	1
P. Wax	4	3	3	1	3
CBS	1.5	1.2	1.2	1.5	1
TMTD	0.5	0.1	0.2	0.25	0.1
Sulfur	2.5	2.5	2.5	1.5	2.25
DPT	2	2.5	2.5	2.5	2.5
Retarder TSA	—	—	0.5	—	0.75
Retarder NDPA	—	0.5	—	—	—
S.G. (unblown)	1.15	—	1.4	1.2	1.5
Cure at 40 psi	30'	40'	60'	60'	60'
S.G. (blown)	0.6	0.64	0.6	0.55	0.79

SPONGE CORE FOR TENNIKOIT RINGS

To make the tennikoit rings soft to feel and light in weight a central core of vulcanized rubber sponge is used. The core is generally extruded and vulcanized in open steam. The top cover is then moulded onto this core. The only physical properties desired are low density and resistance to compression set at low cost.

Synaprene-1712	50
Red reclaim	100
Hard clay	40
Whiting	60
Naph oil	20
Zinc oxide	4
St. acid	4
A.O. PBN	0.5
P. wax	3
CBS	1
TMTD	0.3
Sulfur	2.5
Retarder NDPA	0.3
DPT	3
Red oxide	qs
S.G. (unblown)	1.38
Cure in open stèam at 40 psi	60'
S.G. of blown product	0.3

EBONITE

Synaprene rubbers are used in the manufacture of hard-rubber or ebonite goods. The principal advantages are :

(1) Less exothermic reaction and hence less likelihood of blow-outs and distortion during cure. Also, complete elimination of porosity in the product.

(2) Higher yield temperatures and low plastic yield at higher temps.

Rubbers	**Yield temp. °C**
Natural rubber	80°C
SBR 1500 or 1502	90- 95°C
SBR (1514 & 1513 type)	100-110°C

All compounds at 47 phr sulfur level.

(3) High oil swell resistance and high swell time (i.e. longer time required to swell).

	Volume Swell in liquids %			
Type	**Petrol**	**Benzene**	**Nitrobezene**	**Carbondisulfide**
Natural rubber Ebonite (54 phr. Sulphur)	—	62	27	83
SBR Ebonite (59 phr. Sulphur)	0.1	1.5	0.2	32

(4) Low dielectric loss at higher temperatures. Power-factor and hence dielectric loss of an ebonite based on natural rubber increases very rapidly as the yield point is approaching. Synaprene ebonites (especially Synaprene 1513 & 1514 ebonites) are not only electrically superior to natural rubber ebonites at room temperature but, also retain their good properties to a still higher temperature owing to their high yield temperature.

(5) Ebonite compounds shrink in volume during the cure. (6% volume shrinkage for new rubber + sulfur). Ebonites based on natural rubber, when cured to "ebonite stage" in the mould, are marred by the appearance of "shrink marks" on the product. Synaprene ebonites are not susceptible to shrink marks when cured under similar conditions.

Chemical resistance and impact strength of Synaprene Ebonite is better than that of NR ebonite. However, cross-breaking strength of NR ebonite is superior. Impact strength could be improved by the addition of small quantities of polychloroprene or butyl rubbers (3-5 phr.)

SYNAPRENE SEMI-EBONITES :

When the sulfur level in natural rubber compounds is increased progressively, the vulcanizates show minimum physical strength and poor ageing characteristics at about 12% combined sulfur (rotten rubber-stage) and then the properties progressively improve (leathery stage) with marked increase at about 25% level of combined sulfur (Ebonite stage). Not only Synaprene rubbers do not exhibit these intermediate stages but their properties improve continuously with increase in level of sulfur. The semi-ebonites of Synaprene rubber exhibit good physical properties especially, semi-ebonites of Synaprene 1958 are outstanding. They are as hard as true ebonites, can be cured in as short a cure time as 15 minutes at 152°C and can be obtained in attractive bright colours of any shade. These semi-ebonites can be used in place of ebonites where high temperature performance and high chemical resistance are not required.

✓	**Steering Wheel**		**Coloured Ebonite Rods**	**Toilet Seat**	**Mine Batteries**
	Coloured	*Black*			
	1	2	3	4	5
S-1513/1514	20	60	—	—	50
Synaprene-1958	80	40	100	100	—
RMA-IX	—	—	—	—	50
CR	—	2	—	5	2.5
FEF	—	10	—	—	—
Hard clay	50	100	—	—	—
Whiting	100	150	—	—	—
Cal. Silicate	—	—	30	—	—
Ebonite dust	—	—	—	—	40
Bitumen	—	20	—	—	—
Ar. oil	20	—	—	—	—
Linseed oil	—	—	—	—	5
Cumar	—	20	10	—	—
Zinc oxide	4	4	—	35	—
MgO	—	5	—	—	6
St. acid	2	2	—	—	—
MBTS	—	1.5	1	—	—
TMTM	1.5	—	—	2	—
DOTG	—	—	1	—	—
DPG	—	1.5	—	—	1.5
Sulfur	5	20	15	12	40
TiO_2	qs	—	—	100	—
S.G.	1.60	1.65	1.27	1.77	—
Cure @ 152°C (press)	15'	15'	—	20'	10'
Post-cure @ 40 psi Open Steam	1 hr.	2 hr.*	4 hrs.	—	2 hrs.

*Step cure : @ 20 psi for 1 hr.
@ 30 psi for 1 hr. further.
@ 40 psi for 1 hr. further.
(Selected as an alternate)

SYNAPRENE PROOFING COMPOUNDS

Less scorch hazard of the compounds and better resistance oxidative ageing and metal poisons commend Synaprene rubber for this use. The Non-staining rubbers Synaprene 1502, 1513 ands 1514 are preferred for this use.

To obtain a high adhesion strength between the Synaprene skim coat and the fabric, it is preferable to use an anchor coat based on natural rubber compound. With this procedure it is possible to get an adhesion strength as high as 3.5 kgs/2.54 cms.

	Proofing compound for DT cloth	**Anchor-coat or Friction**
Synaprene-1502	50	—
RMA-1	50	100
Peptiser	—	0.25
Soft clay	150	—
Whiting	150	60
Pptd. $CaCO_3$	50	—
Naph. oil	10	3
Cumar	5	—
W. rosin	—	2.5
Zinc oxide	4	5
St. acid	2	1.5
A.O. SP.	1.5	1.5
P. wax	1.5	—
CBS	1.5	0.1
DPG	0.4	—
ZDC	0.2	0.1
Sulfur	3	2.5
Cure in hot air @ 130°C.	1 hr.	

GROUND SHEETS

Synaprene-1502	100	—
RMA-1	—	100
Soft clay	40	40
Cumar	5	—
Zinc oxide	4	5
St. acid	1	2
A.O. PBN	0.75	0.75
P. wax	0.5	0.5
MBT	1.0	0.6
TMTD	0.2	—
ZDC	0.5	0.2
Sulfur	1.65	2.0
S.G.	1.19	1.19

Cure in hot air @ 130°C	60 minutes.
Adhesion between plies, kg/inch. Unaged	3.5
Aged 150 hours @ 90°C, Kg/inch	2

MATS AND MATTINGS FOR AUTOMOTIVE INDUSTRY

Mattings are normally calendered with the help of design rolls. At times they are backed by jute fabric. Molded mats are also used. Many a times these mattings are vulcanized on formers. Synaprene rubbers help to impart sufficient thermoplasticity for the forming operation.

DU/0871	Good quality	Medium quality		Economic quality
	Coloured	**Coloured**	**Black**	**Black**
Synaprene-1502	100	80	—	—
Synaprene-1712	—	—	80	50
WTR	—	—	40	100
Red reclaim	—	40	--	—
SRF	—	—	30	20
Soft clay	150	100	100	100
Whiting	100	200	200	200
Naph. oil	15	10	10	10
Cumar	3	3	—	—
Bitumen	—	—	5	5
Zinc oxide	3.5	3.5	3.5	3.5
St. acid	1.5	1.5	1.5	1.5
A.O. PBN	—	—	1	1
A.O. SP	1	1	—	—
P. Wax	2	2	2	2
MBT	1	0.9	0.8	0.8
DPG	0.4	0.4	0.4	0.4
Sulfur	2.25	2.5	3	3
TiO_2 & Colour	qs	qs	—	—
S.G. (Actual)	1.67	1.77	1.65	1.76
Cure @ 141°C	20'	20'	20'	20'
T.S.	61	35	42	23
E.B.	475	300	350	210
Hardness	71	69	68	75

ANTISTATIC MAT

Synaprene-1500	100
ISAF	60
Ar. oil	8
Zinc oxide	3.5
St. acid	2.5
A.O. PBN	1
A.O. ETDQ	1.5
P. wax	0.5
CBS	1.2
TMTD	0.1
Sulfur	2.25
Glycerol*	2.0
S.G.	1.15
Cure @ 152°C	10'
T.S.	184
E.B.	325
Hardness	69
Electrical resistance (on surface)	
Dry (megohms)	1.67
Wet (megohms)	0.56

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*To get better antistatic properties, ethylene oxide condensate or quarternary salts should be used.

ROLLER COMPOUNDS

Rubber rollers both of soft rubber and ebonite, are widely used in textile and paper industries. Synaprene rubbers can be blended with natural rubber to improve the calendering characteristics of the compound. Addition of Synaprene rubbers will also overcome any tendency of the compounds to revert during the long cures. Synaprene 1513 and 1514 are preferred for this application. In the manufacture of ebonite rolls, Synaprene 1513 or 1514 can completely replace natural rubber. The advantages of these ebonites are :

(1) less evolution of exothermic heat during curing to ebonite stage with consequent less danger of blow-outs.

(2) The yield point of Synaprene rubber ebonite is higher than natural rubber ebonite and hence Synaprene rubbers are better suited for use at higher temperature.

In addition the uniform quality of Synaprene rubbers and the relative freedom of their compounds from scorch are additional processing advantages.

For building-tack good quality resins like cumar, alkyl-phenol formaldehyde could be used. Building-tack could be also improved by using highly masticated natural rubber (about 25 phr).

Synaprene 1513 improves the pliability of roller compounds due to its inherent characteristic like low viscosity.

Being less unsaturated, Synaprene 1513 and 1514 require lower quantities of sulfur for conversion to ebonite stage. 30 to 42 phr sulfur, gives good hard ebonites.

For soft rubber rollers Synaprene rubber vulcanizates offer the following advantages :

(1) Uniform hardness of 'Face' compound.

(2) Low 'Plastometric set' or the ability to recover completely between each cycle of contact.

SOFT RUBBER ROLLER COMPOUNDS

	COVER COMPOUNDS		Ebonite Base Stock
	80 SH	85 SH	
Synaprene-1513/1514	30	50	—
RMA-1X	70	50	100
Hard clay	120	150	—
Red iron oxide	—	—	50
Zinc oxide	5	10	50
Magnesium oxide	10	2	10
Cumar	6	6	2
St. acid	2	2	1
A.O. PBN	1	1	—
MBTS	1.5	1.5	—
DOTG	0.3	0.15	—
DPR-5	—	—	1.5
Sulfur	5	6	40
S.G.	1.49	1.56	—

Cure in open steam: 1 inch thickness; one hour at each progressively increased steam pressures of 20, 25, 30 and 40 psi.

NOTE: For greater thickness, the accelerator dosage will have to be reduced and cure time correspondingly increased. A solution of the base stock in petroleum solvent should be applied to the core and then after evaporation of the solvent, layers of the base stock should be applied. Petroleum solvents can be used for revival of surface tack. However, due care should be taken to ensure that all solvent has evaporated before building up the roll.

EBONITE ROLLER COMPOUNDS

	Cover Compound 1	Cover Compound 2	Base Stock 3	Solution for core 4
S-1514	100	50	—	—
RMA-1	—	50	100	100
Soft clay	150	150	80	—
Cal. Silicate	—	—	—	20
Zinc oxide	—	—	—	20
Mag. oxide	6	2	10	—
Linseed oil	6	5	5	—
MBTS	—	—	—	1
DPG	1.5	1.5	1.5	—
Sulfur	30	35	45	20
Carbon black	2	2	2	—
Red oxide	—	—	—	20
S.G.	1.84	1.74	—	—

Cure 1" thickness in direct steam.

STEP-CURES

20 psi	60 minutes
20 psi	60 minutes
30 psi	60 minutes
40 psi	60 minutes

NOTE: For greater thickness the accelerator dosage will have to be reduced and cure time correspondingly increased.

	Typewriter Roll ✓	Wringer Roll ✓
Synaprene-1502/1513	100	100
FEF	60	—
Hard clay	50	150
Pptd. $CaCO_3$	50	50
Al. Silicate	—	25
Light $MgCO_3$	10	—
Cumar	7	10
P. Jelly	—	5
Zinc oxide	10	5
St. acid	1.5	1
A.O. SP	1.5	1.5
MBTS	1	1.5
MBT	0.5	—
TMTM	—	0.6
Sulfur	20	2.5
TiO_2	—	15
S.G.	1.54	1.79
Cure @ 152°C	40'	10'
T.S.	121	57
E.B.	50	550
Hardness	90	68

TYPEWRITER ROLL :

A preliminary step in the manufacture of typewriter rolls is extrusion of the raw stock in the form of tubes. Extrusion of stiff high hardness compound is difficult. There is a considerable rise in temperature of the stock and hence a constant danger of scorching of the stock. But Synaprene compounds can be extruded without trouble because of their relatively high scorch safety.

WRINGER ROLL :

Wringer rolls are prepared by moulding directly in a mould, or vulcanising an extruded tube on a mandrel or built up from calendered sheets. The compound given above is suitable for moulding or extrusion method.

PRINTING ROLLS

Glue composition rolls were being used earlier for printing. But at present, rubber rolls are becoming popular because of their better performance on high speed machines.

Printing rolls are manufactured by using Nitrile and/or Synaprene rubbers to get adequate oil and solvent resistance. Oil and solvent resistance is required to a certain extent because of the types of inks used and the cleaning procedures.

	Premium Quality	Medium Quality
Synaprene-1513/1514	50	—
Synaprene-1712	—	100
NBR (High)	50	—
FEF	20	30
Pptd. $CaCO_3$	20	—
Brown factice	35	20
P. Jelly	10	5
Ar. oil	—	20
Naph. oil	20	30
DBP	20	—
Cumar	4	7
Zinc oxide	5	4
St. acid	2	1.5
A.O. PBN	1	1
MBTS	1.5	0.75
MBT	—	0.5
Sulfur	2	1.7
Cure in Open steam @ 40 psi, 1" thickness	90'	90'
Hardness	30	30

TANK LINING

Synaprene rubbers being resistant to solution of acids, alkalis and salts are used for the protection of metal equipment in a similar manner as natural rubber is used. They are used both for soft rubber lining or ebonite lining.

METHODS OF APPLICATION :

The metal is cleaned free from rust, dust or other coatings by scoring, wire brushing, sand blasting or shot-blasting. The metal surface is then cleansed with solvent to remove oil and grease and there after bonding agent is applied. For ebonite lining a cement made from natural rubber ebonite compound is applied. For soft rubber linings three types of cements are available:

(1) *Cyclised rubber cement*: These cements give a bond strength of the order of 30-35 kg/cm^2. However, the cements being thermoplastic the bond strength falls rapidly as temperature increases.

(2) *Chlorinated rubber/Neoprene cements*: This is a two coat method. The first coat or the primer coat consists of a mixture of chlorinated rubber and dispersed red lead in an aromatic solvent. After drying of the first coat second coat of a solution of vulcanizing type of neoprene compound in aromatic solvent is applied. The rubber lining is applied on this second coat.

(3) *Rubber hydrochloride cement*: This is by far the most satisfactory and popular cement used.

All these above cements can be used for various vulcanization method like open steam, hot air, or hot water.

Isocyanate bonding agents are used for soft rubber lining. But care should be taken in handling as they are very prone to moisture.

The compound is sheeted out on a mixing mill or a calender and plied up to get the necessary thickness. It is advisable to rerun the plied up calendered sheet from one liner in which it was originally wrapped onto another liner. During this operation the liner should be wound with the sheet under a higher tension. The sheets should then be allowed to rest for 24 to 72 hrs to enable to diffuse away any air entrapped and to allow the plies to fuse well together. This process, also reduces the tendency of the sheet to shrink when heat is applied.

The rested rubber sheet should be applied to the metal, holding the sheet at a correct angle to avoid any entrapment of air between the metal and the rubber sheet.

When two ends of rubber sheets are to be joined together, the joints can be made by over lap bevel joints or strapped joints. In the former method the sheet edges are skived and one sheet is overlapped over the other sheet, the overlapping being 0.5 to 1.25". In the second method the two sheets are skived and flush jointed with each other. A strip of the compound of width not over 2 inches is stuck over the joint line.

Vulcanising of the lined vessel can be carried out in open steam, hot air or under hot water depending on the type of vulcanizing equipment available. When curing is by hot water it is essential to have the water level higher than the rubber lined metal and care should be taken to avoid the direct steam pipe being placed too near the unvulcanized sheet otherwise blisters will result in the sheet.

EBONITE LINING

	Autoclave cure. ✓	Hot water cure. ✓	Cement for metal ✓
Synaprene-1514	50	50	—
RMA-1	25	25	100
Reclaim WTR-SR	50	50	—
Hard clay	100	100	—
Barytes	50	50	—
Cal. Silicate	—	—	20
Linseed oil	6	6	—
Magnesium Oxide	6	4	—
Zinc Oxide	—	—	20
MBTS	—	1.5	1
BA	1.5	—	—
TMTD	—	0.4	—
Sulfur	40	40	20
Red Oxide	—	—	20

Cure:	Open Steam	Hot Water
(4 mm thick)	30 psi 1 hr.	@ 100°C
	30 psi 1 hr.	120 hrs.
	40 psi 4 hrs.	

SOFT RUBBER TANK LINING

	Lining compound (1)†	(2)
Synaprene-1502	80 ✓	80
Synaprene-1513	20	20
Barytes	100	100
China clay	—	50
ZnO	100	5
Brown Factice	10	10
Naph. Oil	5	5
Cumar	15	15
P. Wax	4	4
St. Acid	1	1
Retarder NDPA	0.5	0.5
ZMBT	3	3
ZDC	1.2	1.2
Sulfur	2	3
A.O. SP.	1.5	—

	Bonding Solution (3)
RMA-1	100
ZnO	25
Red oxide	25
Cumar	25

Make 20% solution in Rubber Solvent

Cure: 24 hrs. in Boiling water
(3 mm)

Also prepare 50% solution chlorinated rubber in toluene.

At first apply thin uniform coat of chlorinated rubber solution with equal parts of Isocyanate Bonding agent and allow to dry. Then apply one coat of Bonding solution. When solution is dried and sufficiently tacky lay the rubber sheets.

†*Test Solutions*		*% Vol. Change After Two Months*
Dilute HCl	..	8.11
10% NaOH	..	—2.046
10% NaCl	..	0.2008
10% $CaCl_2$	..	—0.4506

REMARKS : All the specimens maintain their shapes, but the specimen in dilute Hydrochloric acid is turned slightly brown. It is slightly swollen too. Hence for acid service zinc oxide should be brought to 5 parts and 50 phr china clay should be added.

MISCELLANEOUS GOODS

FOOT-BALL BLADDER : Addition of Synaprene 1502 to foot-ball bladder compound will widen temperature range over which the compounds could be calendered faultlessly. Synaprene 1502 will increase scorch resistance of the compound and also ability of the scrap to be reworked. For better calendering characteristics and better air-retentivity in the tube Synaprene 1513/1514 can be used.

PLAY BALL : Green blanks for play-balls are prepared by various methods, which require skilled workmanship. The blowing mixture should be prepared carefully. Sodium nitrite 10 pbw; sal ammoniac (NH_4CL) 10 pbw; Epsom salt ($MgSO_4 . 7H_2O$) 5 pbw and zinc stearate 0.5 pbw should be separately powdered and mixed thoroughly. Tableting of the blowing mixture minimises variations in blowing. One gram of this mixture is sufficient for 50-60 cc. of ball-volume.

LEATHER-LIKE BELTS : Leather is getting scarce and its cost is rising high. New types of leather like materials (poromerics) are coming up in other countries. Excellent leather like materials could be developed by using Synaprene 1958 the self-reinforcing rubber. Various products like luggage materials and footwear materials could be easily manufacture by using conventional machineries for easy processing.

INSULATING TAPE : Good resistance to oxidation by Synaprene 1513 and 1514 in unvulcanized state makes them useful for the manufacture of insulating tapes. The dough of the compound is prepared in rubber solvent or in a mixture of toluene and petroleum naphtha.

	Foot-ball Bladder	**Play-ball**
Synaprene-1502	20	50
Synaprene-1513	20	—
Pale crepe	—	50
RMA-IX	✓ 60	✓ 50
Peptiser	—	0.25
Hard clay	40	80
Soft clay	—	80
Pptd. $CaCO_3$	40	70
Naph. oil	15	10
Brown factice	5	—
Cumar	—	7.5
Zinc oxide	4	4
St. acid	2	2
A.O. SP	1.5	1
P. Wax	—	2
MBTS	0.7	1.4
MBT	0.7	—
TMTD	—	0.2
DOTG	0.5	—
Sulfur	1.5	0.2
TiO_2 & Colour	qs	qs
S.G.	1.25	1.47
Cure @ 152°C	5'	10'
T.S.	194	96
E.B.	620	525
Air-aged @ 70°C for 168 hrs.		
△ T.S.	— 6	—
△ E.B.	—15	—
△ Hardness	+ 4	—

	Leather like belts		Insulating
	Coloured	**Black**	**Tape**
Synaprene-1502	33	33	—
Synaprene-1513/1514	—	—	50
Synaprene-1958	67	67	—
RMA-IX	—	—	25
WTR	—	—	50
FEF	—	33	—
Hard clay	20	—	—
Pptd $CaCO_3$	67	—	—
Rayon Flock	10	10	—
Hard bitumen	—	—	50
Ester gum	—	—	10
Pine tar	—	—	10
P. Oil	3	3	—
Castor oil	—	—	5
Cumar	7	7	—
P. Wax	1.5	1.5	—
Zinc oxide	7	7	50
St. acid	1	1	—
A.O. SP	1.5	1.5	—
A.O. Metal Inhibitor	—	—	1
MBTS	0.33	0.33	—
MBT	1	1	—
ZDC	0.33	0.33	—
Sulfur	1.66	1.16	—
TiO_2 & Colour	qs	—	—
S.G.	1.45	1.12	1.2
Cure	*	*	—

*Hot air cure: 90'

@ 75 psi steam pressure (Jacket).
@ 30 psi air pressure (Vessel).

MOULDED SOLES AND HEELS

Synaprene rubbers are extensively used for this purpose. Synaprene rubbers when properly reinforced have excellent abrasion resistance; flex resistance (resistance to cut initiation) and resistance to compression-set. Synaprene rubbers can be easily extended by higher loadings of filler and oil for reduction in volume cost of the compound.

NEOLITE SOLING (Resin Soling) : is now fast replacing leather as a soling material for stuck-on shoes and chappals. The advantages are lightness, excellent abrasion resistance and flex resistance coupled with appearance, feel and working characteristics of leather. Other additional advantages are the colorability, resistance to moisture and mildew, and ease of fabrication (moulding vs. manual fabrication from leather).

These soling materials are required to have high hardness, high stiffness and low specific gravity. Synaprene 1958 helps to achieve the hardness and stiffness without the use of high loadings of filler, and thereby, gives easy processing compounds and light products. Synaprene 1958 compounds are stiffer when cold but are very thermoplastic at high temperature. These characteristics help to get fault-free glossy products with very thin flash, even in moulds with complicated design. The excellent advantages of Synaprene 1958 are developed to the optimum only if Synaprene rubbers (S-1502, S-1513, S-1514) are blended with it rather than with natural rubber.

COLOURED MOULDED SOLING

Synaprene-1502	100	100	100
Hard clay	150	200	250
Naph. Oil	10	15	20
Cumar	10	10	10
Zinc oxide	4	4	4
St. acid	1.5	1.5	1.5
A.O. PBN & DPPD*	1	1	1
MBTS	1	1	1
DPG	1	1	1
DEG	2	2	2
Sulfur	2	2.5	3
TiO_2 & Colour	qs	qs	qs
S.G.	1.42	1.57	1.63
Cure @ 152°C	10'	10'	10'
T.S.	120	99	69
E.B.	585	480	355
Hardness	68	71	75
Flex 1	392	260	100
Abrassion Index	45	51	76

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*Only for dark coloured products. For light coloured products Antioxidant Styrenated Phenol should be used.

MOULDED BLACK SOLING

	✓ 1	2	3
Synaprene-1502	100	100	100
HAF	30	40	50
Hard clay	100	150	200
Naph. oil	30	40	50
Cumar	7	7	7
Zinc oxide	4	4	4
St. acid	1.5	1.5	1.5
A.O. PBN & DPPD	1.5	1.5	1.5
P. Wax	2	2	2
MBTS	1	1	1
DPG	1	1	1
Sulfur	2	2.5	2.75
S.G.	1.32	1.43	1.5
Cure @ 152°C	10'	10'	10'
T.S.	100	78	65
E.B.	400	315	300
Hardness	63	71	73
Flex 1	400	390	210
Abrasion Index	87	95.0	92.0

	NEOLITE SOLING		LEATHERY INNER SOLE Banwar	
	1	2	3	4
Synaprene-1502	40	40	50	40
Synaprene-1958	—	—	50	60
SRF	20	—	20	—
Cal. Silicate	—	20	—	—
Hard clay	100	100	100	100
Naph. oil	5	5	5	8
Cumar	3	3	5	5
P. Jelly	—	—	2	2
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	1.5
A.O. SP	1	1	1	1
P. Wax	1	1	0.5	0.5
MBTS	1.3	1.3	1.5	1.5
TMTD	0.3	0.3	0.4	0.4
DEG	—	2	—	—
Sulfur	2	2	2.25	2.25
TiO_2 & Colour	—	qs	—	qs
S.G.	1.45	1.45	1.45	1.36
Cure @ 162°C	5'	5'	5'	5'
Hardness	90	88	90	92
Tear S.	52	51	50	42
Flex I	200	200	200	151

NOTE: 5 phr. TiO_2, 0.05-0.1 Orange colour and a trace of black will give the required beige to leather like colour.

[redacted]

MICROCELLULAR SOLING

Microcellular rubber soling has become very popular in the Footwear Industry and is still getting more popular even though new man-made materials are springing up. The advantages offered by microcellular rubber solings are :

(1) Light weight (i.e. low density) for comfort.

(2) Minimum abrasive-wear for long life.

(3) Long flex-life.

(4) Versatility of hardness range (very soft to hard)

(5) Ability to give bright pastel shades and also transluscency-effect.

(6) Most Hygenic.

(7) Requires conventional adhesives for bonding.

The recent trend is to use hard microcellular rubber soling for shoes and sandals, medium hard for chappals with leather or other types of uppers, soft and very soft for Hawai or beach sandles. It is also a fast catching up practice, to paste neolite insole (Banwar) with medium hard microcellular soling for variety of chappals and sandals.

Unlike the manufacture of rubber sponge article, the mould should be fully loaded with 3 to 5% excess compound kept under full hydraulic pressure. The excess loading helps in giving a flash all around which seals off the mould-frame and prevents leakage of decomposed gas. Under the high pressure the decomposed gas (mostly nitrogen) gets trapped in the rubber matrix and after partial cure, when the external pressure is released by sudden opening of the mould, the precured sheet pops out due to high internal pressure and expands considerably. The rubber sheet gets a fine microporous structure

	NEOLITE SOLING		LEATHERY INNER SOLE Banwar	
	1 ✓	2	3	4
Synaprene-1502	40	40	50	40
Synaprene-1958	—	—	50	60
SRF	20	—	20	—
Cal. Silicate	—	20	—	—
Hard clay	100	100	100	100
Naph. oil	5	5	5	8
Cumar	3	3	5	5
P. Jelly	—	—	2	2
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	1.5
A.O. SP	1	1	1	1
P. Wax	1	1	0.5	0.5
MBTS	1.3	1.3	1.5	1.5
TMTD	0.3	0.3	0.4	0.4
DEG	—	2	—	—
Sulfur	2	2	2.25	2.25
TiO_2 & Colour	—	qs	—	qs
S.G.	1.45	1.45	1.45	1.36
Cure @ 162°C	5'	5'	5'	5'
Hardness	90	88	90	92
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MOULDS : The construction of a mould should be such as to allow uninhibited expansion of the sheet immediately on release of the external pressure otherwise the sheets will warp and deshape.

The mould-frame, therefore, has bevelled edges (45°) so that on release of pressure the sheet pops out of frame and expands freely.

The principle of manufacture depends on the containment of the gas in the rubber matrix during the precure stage. The mould design must be such that completely leakproof effective closure of the mould occurs under pressure. The faces of the mould-frame and the mould-lid must be ground flat and true.

Considerable expansion of the sheet occurs after release from the mould. The expansion will depend on the compound, precure time and the expected final density of the product. As a rough guide the expansion (based on mould dimensions) to be allowed during the design of the mould can be taken as 30-40% for soft (Hawai) soling and about 15-20% for hard microcellur soling.

Ordinary mild steel can be used for the fabrication of the mould. However, when it is desired not to have a design on top surface of the sheet e.g. microcellular sheet to be used for leather-top chappals, the top lid of the mould can be dispensed with and the platen of the press can be used as the closing lid of the mould.

PRESS : Microcellular sheets can be manufactured both in hand presses and hydraulic presses. But in hand presses the alignment of platen is never perfect and it is very difficult to get the perfect closure of moulds which is very essential for microcellular sole production. Another difficulty is that it is very difficult to open the press quickly. Initially it is easy to close the mould and the press gets mechanically locked after the closure. However, after precure, there is a heavy force acting on the mould because of the pressure of the gas. Many times, it becomes very difficult to open the press quickly. The sheet may become distorted if the opening time is too long, and also because of the varying precure it is difficult to get sheets of constant dimensions.

Multidaylight hydraulic presses are best suited for the production of microcellular soling because: (1) the mould closes under positive pressure thereby ensuring perfect closure of the mould. (2) The pressure release and opening of the mould is quick.

HYDRAULIC PRESSURE : The pressure required for closure is similar to that in case of moulding of other rubber compounds of corresponding viscosity. In case of microcellular soling however, there is one distinction. During cure the blowing agent decomposes and an internal pressure is developed in the compound tending to open the press. If the hydraulic pressure is not adequate the mould will open up and the gas will escape giving a defective product. The minimum pressure (known as specific pressure) necessary to keep the mould closed will depend on the amount of blowing agent in the compound. The pressure is approximately 18 kg/cm^2 per phr. for DPT type blowing agent in the compound, thus a compound containing 4 phr. blowing agent will have a back-pressure of 72 kg/cm^2. The closing force on a mould of dimensions 23 cm x 27 cms. will have to be higher than 23 x 27 x 72 kgs. or about 45 tons.

Hence, it must be checked that the hydraulic pressure on the mould is adequate for the compound and the size of the mould.

Higher pressures than the minimum are always beneficial in the production of microcellular soling giving a lighter product with finer and more uniform cellular structure.

SYNAPRENE RUBBERS IN MICROCELLULAR

Use of high styrene resins of the self-reinforcing rubber Synaprene 1958 is a must for the manufacture of any good quality microcellular soling. It is only because of this rubber that even at low density the product has the necessary toughness and the best abrasion resistance.

Synaprene 1958 can be blended either with natural rubber or the non-staining Synaprene rubbers 1502, 1513 or 1514. Synaprene 1502, 1513 and 1514 have many advantage to offer for these applications.

(1) With natural rubber it is necessary to masticate the rubber to a constant controlled viscosity. The degree of mastication has to be critically controlled as it affects the expansion. With Synaprene 1502, 1513 and 1514 no mastication is necessary thus increasing the mill-room production and doing away with the need of continuous control on the mastication.

(2) The expansion of the sheets is critically dependent on the degree of precure. With the varying cure-rates of natural rubber, it is difficult to get sheets with constant dimensions and quality. The uniform cure rates of Synaprene rubbers are a boon.

(3) Synaprene 1502, 1513 and 1514 are water white in colour and hence less quantity of Whitening pigments are necessary.

In finished products :—

(1) Synaprene rubbers give sheets with more expansion thus giving light weight products.

(2) The split tear strength of the product is high.

(3) Excellent abrasion and age resistance and long flex life.

PROBLEMS DURING MICROCELLULAR SOLING MANUFACTURE :

(a) *Coarse spongy structure* :

Spongy structure is mainly due to underweight blank. Slightly underweight blank will give the coarse structure limited only to the top and bottom side of the sheet. With a grossly underweight blank the whole sponge structure is coarse. The latter defect can also occur with hydraulic pressure less than the minimum specific required.

(b) *Variation in dimensions* :

The size of the sheet depends on the degree of precure. If the precure is less the dimensions will be larger. If the precure is higher the sheet dimensions will be smaller. The variation in degree of precure may occur due to variation in the cure rates of the batches. For a slow curing batch either the precure time should be increased or addition of a small quantity of sulfur will help to restore the cure-rate of the batch. For a fast curing batch the precure time should be decreased.

(c) *Irregular shapes of the sheets* :

This defect occurs due to imperfect seal and leakage of gas from the mould either due to a faulty mould or the non setting of the flash before the internal pressure starts building up. In either case there will be continuous ejection of spew during the precure. The non-setting of the flash can be due to thickness (excessively overweight blank) or due to very low setting nature of the compound. In the latter case addition of some booster accelerator will help.

This defect can also occur because of :

(1) inadequate moulding pressure and

(2) improper size of the blank, the compound flowing out before completely filling the cavity.

(d) *Blister formation at the time of pressure release*:

This defect is either due to

(1) undercure (the blister wall surface reveals an irregular rugged surface, or

(2) entrapped air in the blank (the blister wall is smooth) or

(3) improper dispersion of the blowing agent.

(e) *Blister formation at the time of post cure* :

This is due to incomplete decomposition of the blowing agent during precure. Hence, the precure time should be increased (at lower temperature if necessary) or the blowing agent level should be decreased.

(f) *Perfect sheets at the time of pressure release, but start cracking on standing* :

This can occur due to

(1) excessive blowing agent

(2) Overcure and

(3) Weak cell-wall (insufficient reinforcement).

This can be due to low level of fillers used or low reinforcing ability of the filler. Increase in the level of filler or addition of a good reinforcing filler will overcome this defect. These points should be clearly kept in mind while using clays or indigenous Silica-Silicate type fillers as the reinforcing fillers in Synaprene compounds.

USE OF CRUMBS :

Microcellular crumbs of around 40 to 100 Mesh could be used in microcellular compounds. 40 to 50 phr could be easily mixed without much affecting the quality. Higher quantity of crumbs bring down the tear strength and abrasion resistance considerably. Apart from lowering the cost, crumbs offer advantages like low shrinkage light weight and faster cure time.

MICROCELLULAR COMPOUNDS FOR 25–45 SH A

	1	2	3	4
Synaprene-1502	75	—	—	—
Synaprene-1514	—	75	75	50
Synaprene-1958	25	25	25	50
Al. Silicate (Ind.)	20	—	—	—
Hard clay Q.C.4	100	120	100	100
Cumar	—	5	5	4
Naph. oil	30	60	30	20
Zinc oxide	4	4	4	4
St. acid	6	6	6	6
A.O. SP	0.8	1	1	1
P. wax	1	1	1	1
MBTS	1.1	1.1	1.1	1.1
TMTD	0.15	0.2	0.15	0.1
Sulfur	2	2	2	2
DPT	6.5	6.5	6.5	6.0
TiO_2	10	5	5	10
Colour	qs	qs	qs	qs
S.G.	1.38	1.3	1.3	1.34
Cure @ 152°C	8'	8'	8'	8'
Hardness	38	25	38	43
Expansion %	37	32	30.5	38
Shrinkage %	1.8	2.4	2.6	1.8
Split tear	5.4	4.6	6.0	11.0
Comp. set %	39.0	36.5	14.0	14.6

MICROCELLULAR COMPOUNDS FOR 46–65 SH A

	1	2	3	4
Synaprene-1502	50	—	—	—
Synaprene-1514	—	50	50	50
Synaprene-1958	50	50	50	50
Al. Silicate	40	60	—	—
Cal. Silicate	—	—	40	50
Hard clay	40	20	60	50
Mag. carbonate	—	20	—	—
Cumar	—	4	4	—
Naph. oil	20	15	25	15
Zinc oxide	4	4	4	4
St. acid	4.5	4.5	5.0	4.5
A.O. SP	0.8	1	1	0.8
P. Wax	1	1	1	1
MBTS	1.1	1.1	1.1	1.1
TMTD	0.15	0.1	0.15	0.15
DEG	1	1	1	1
Sulfur	2	2	2	2
DPT	5	4	4.5	4.5
TiO_2	10	—	5.0	—
Colour	qs	qs	qs	qs
S.G.	1.32	1.26	1.3	1.3
Cure @ 152°C	8'	8'	8'	8'
Hardness	53	53	61	58
Expansion %	39	28	39	37
Shrinkage %	5.8	8.1	3.1	0.58
Split tear	6.0	7.5	6.5	6.0
Comp. set %	25	22.8	20.6	18.7

MICROCELLULAR COMPOUNDS FOR 66-85 SH A

	1	2	3	4
Synaprene-1502	50	25	—	—
Synaprene-1513/1514	—	—	30	20
Synaprene-1958	50	60	70	60
RMA-1	—	15	—	20
Al. silicate	50	—	—	—
Ca. silicate	—	—	50	40
Hard clay	50	90	20	80
Cumar	2	4	5	—
Naph. oil	15	4	10	5
Zinc oxide	4	3	4	4
St. acid	4.5	4	3.5	4
A.O. SP.	0.8	0.8	0.8	0.8
P. Wax	1	1	1	1
MBTS	1.1	1.1	1.2	1.2
TMTD	0.1	—	0.2	0.1
DEG	1	—	1	—
Sulfur	2	1.8	1.8	2
DPT	4.5	3.5	3	3
TiO_2	10	15	2	qs
Colour	qs	qs	qs	qs
S.G.	1.38	1.41	1.23	1.44
Cure @ 152°C	8'	8'	8'	8'
Hardness	73	68	78	73
Expansion %	28	41	18.5	30
Shrinkage %	1.5	2.1	1.00	0.61
Split tear	10	8.8	13.25	7.0
S.G. (Blown)	0.66	0.48	0.45	0.23

HOT AIR CURED FOOT WEAR

Natural rubber was the principal rubber used in this industry because of its good green tack and the ease of fabrication. Now the better abrasion resistant Synaprene rubbers are being increasingly used in this industry either as partial or complete replacement of the natural rubber. The advantages of Synaprene rubbers over natural rubber in this field are :

(1) *Very little increase in compound plasticity on continued working.*

(2) *Greater Scroch Safety* : Compounds for hot air cure have to be necessarily fast curing with high levels of booster accelerators. Such compounds are very scorchy. Replacement of the natural rubber by Synaprene rubber, either partly or wholly will increase the scorch safety even when such compounds are adjusted for equal cure-rate.

(3) *Flat cures* : In hot air cures especially where there is no circulating fan there is always a temperature variation as much as 10°C in the vulcanizer during cure. Boosted natural rubber compounds exhibit pronounced peakiness of cure with the result that products are either overcured and reverted or remain undercured. It is very difficult to achieve a tight optimum cure. The physicals are therefore lower and the set (the main reason for deformation of the product during storage) is high. Synaprene rubbers do not revert and hence give compounds whose vulcanizate properties are unaffected by the slight overcures. Even on slight overcures natural rubber vulcanizate become tacky and the product loses sale's appeal. Synaprene compounds are free from this defect.

(4) *Resistance to oxidative degradation* : Natural rubber is very susceptible to oxygen at high tempratures above 100°C. In hot air cures the products have necessarily to be maintained at elevated temperature for prolonged time. Natural rubber compounds are affected by oxygen in the air at high pressure especially in cold zones where the rate of set up is low. Products in cold zone therefore never attain the optimum physicals and have high set. Synaprene rubbers are more resistant to oxidative degradation at high temperatures and hence suffer far less. Synaprene vulcanizates too exhibit resistance towards oxidative degradation.

(5) *Improved sharpness and retention of embossed designed.*

(6) *Freedom from sagging or distortion during the prolonged cure.*

The difference in green tack and shrinkage between Synaprene compounds and natural rubber compounds should be noted while fabricating footwear from the compound, based on Synaprenes and its blends with natural rubber.

(1) LOW GREEN TACK : Synaprene compounds exhibit lower green tack. But by blending with natural rubber or using tackifiers like coumarone indene resin, the green tack could be increased. It is reported that, in Japan, all SBR soles are used for hot air cured footwear. By using all natural rubber cement and foxing the adhesion of the sole to the upper is found to be more than adequate.

(2) GREEN SHRINKAGE : Calendered Synaprene compound stock shrinks to a greater extent than natural

rubber stock. This shrinkage can be reduced by the use of high-structure blacks like FEF, Clay or replacing part of the polymer by reclaim. Otherwise, the sheet should be calendered to thinner gauge and then immediately cooled in water. By this method it is possible to get calendered sheets of constant gauge. The design is slightly altered because of the shrinkage. In the assembled footwear, where the sole is attached firmly to a non-shrinking rag compound of insole, the sole does not exhibit any shrinkage during cure. The cement compound used for fabrication should be slightly faster setting to hold the sole fast.

The compounds given on the following pages cure satisfactorily in hot air vulcanisers (Air pressure 40 psi, jacket steam pressure 75 psi) in about 60 minutes. The flex results shown are taken on shoe soles vulcanized in the hot air vulcanizer in our laboratory and in a shoe factory. However, each type of hot air vulcanizer has different time temperature relations and the accelerator system may need slight modifications to suit the different conditions.

CANVAS SHOE SOLE GRADE A

Synaprene-1502	30	—	—	—
Synaprene-1513/1514	—	—	50	—
Synaprene-1712	—	30	—	50
RMA	70	70	50	50
HAF	—	30	—	35
FEF	30	—	35	—
Hard clay	40	50	60	60
Whiting	20	10	—	—
Cumar	4	4	4	4
Naph. oil	12	—	15	—
Ar. oil	—	10	—	15
Zinc oxide	4	4	4	4
St. acid	1.5	1.8	1.5	2
A.O. PBN	0.5	0.5	0.5	0.5
A.O. PBN & DPPD	0.5	0.5	0.5	0.5
P. wax	1	1	1	1
MBT	0.6	0.6	0.6	0.6
MBTS	0.6	0.6	0.6	0.6
DPG	0.4	0.4	0.6	0.6
TMTD	0.2	0.2	0.2	0.2
Sulfur	1.75	1.65	1.6	1.6
S.G.	1.28	1.28	1.28	1.28
Cure @ 141°C	15'	10'	15'	15'
T.S.	151	185	164	163
E.B.	450	515	390	440
Hardness	62	61	63	63
Flex 1	400	400	400	400
Abrasion Index	93.6	86	102	90

CANVAS SHOE SOLE GRADE B

Synaprene-1502/1513	30	—	—	—
Synaprene-1514	—	30	50	—
Synaprene-1712	—	—	—	50
RMA	70	70	50	50
HAF	—	—	—	15
FEF	15	15	15	—
Hard clay	75	75	100	100
Whiting	75	75	50	50
Naph. oil	20	20	20	—
Ar. oil	—	—	—	20
Cumar	5	4	6	6
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	2
A.O. PBN	0.4	0.4	0.4	0.4
A.O. PBN & DPPD	0.4	0.4	0.4	0.4
P. Wax	1	1	1	1
MBTS	0.75	—	0.75	—
MBT	0.5	—	0.5	—
CBS	—	1.2	—	1.2
DPG	0.4	0.4	0.4	0.4
TMTD	0.2	0.2	0.2	0.2
Sulfur	1.75	1.65	1.6	1.6
S.G.	1.47	1.47	1.47	1.47
Cure @ 141°C	10'	10'	10'	10'
T.S.	120	108	100	100
E.B.	500	475	550	525
Hardness	60	62	60	60
Flex 1	150	150	150	—
Abrasion Index	83	69	87	81

COLOURED CANVAS SHOE SOLE

	High Grade		Casual B Grade	Casual Competitive
Synaprene-1502	25	25	25	50
Synaprene-1513	25	25	25	—
RMA-IX	50	50	50	25
Red Reclaim	—	—	—	50
Hard clay	40	—	60	130
Light $MgCO_3$	10	10	10	20
Pptd. $CaCO_3$	50	90	80	—
Whiting	—	—	10	90
P. oil	7	7	8	5
Cumar	5	5	5	5
Zinc oxide	4	4	4	4
St. acid	1.5	1.5	1.5	1.5
A.O. SP	1	1	1	1.5
P. Wax	0.5	0.5	0.5	1
MBT	0.6	0.6	0.7	0.6
MBTS	0.6	0.6	0.6	0.6
DPG	0.3	0.3	0.3	—
DOTG	—	—	—	0.6
TMTD	0.3	0.3	0.3	0.2
Sulfur	2	2	2	2.2
TiO_2 and Colour	qs	qs	qs	qs
S.G.	1.36	1.38	1.44	1.64
Cure @ 152°C	5'	5'	5'	10'
T.S.	105	99	83	63
E.B.	420	420	440	560
Mod. 300%	61	53	43	—
Hardness	62	58	63	63
Tear S.	34	30	28	—
Abr. Loss	4.05	4.45	7.60	—
Flex 1	382	254	240	198

KNEE BOOT COMPOUNDS

	SOLES		UPPERS	
	1	2	3	4
Synaprene-1502	50	—	25	—
Synaprene-1712	—	50	—	25
RMA-IX	25	25	75	75
WTR	50	50	—	—
FEF	—	30	20	20
GPF	30	—	—	—
Hard clay	100	100	40	40
White clay	30	30	60	60
Ar. Oil	—	15	—	—
Naph. oil	15	—	—	—
P. oil	—	—	7	5
Cumar	5	5	—	—
Zinc oxide	4	4	10	10
St. acid	1.5	2	1.2	1.2
A.O. PBN	0.4	0.4	0.5	0.5
A.O. PBN & DPPD	0.4	0.4	0.4	0.5
P. Wax	1	1	—	—
CBS	—	1.2	—	—
MBT	0.25	—	0.75	0.7
MBTS	1.0	—	0.75	0.6
DPG	0.4	0.4	—	—
DOTG	—	—	0.25	0.4
TMTD	—	—	0.1	0.1
Sulfur	1.6	1.6	1.85	1.7
S.G.	1.48	1.47	1.45	1.45
Cure @ 141°C	15'	15'	10'	15'
T.S.	83	82	146	138
E.B.	355	550	460	460
Hardness	70	68	53	51
Flex 1	400	400	—	—
Flex 2A	—	—	No cracks > 200	
Abrasion Index	175.4	76	—	—

CANVAS SHOE COMPOUNDS

	✓ **Spreading compound**	**Innersole**	**Sponge Insole***
Synaprene-1502	30	100	100
RMA 1X	70	—	—
Peptiser TBN	0.15	—	—
Hard clay	—	200	100
Whiting	250	200	—
Naph. oil	2	25	35
Cumar	3	3	—
Zinc oxide	4	4	4
St. acid	1.5	1.5	4
A.O. SP	1	—	1
MBTS	1.2	1	1.8
DPG	0.3	1	—
ZDC	—	—	0.25
Sulfur	2.5	7	4
Cloth cuttings	—	15	—
DPT	—	—	1.5
S.G.	1.78	1.83	1.32
Cure @ 152°C	7'	7'	10'
T.S.	—	34	—
E.B.	—	325	—
Hardness	—	77	—
S.G. (Blown) at 50% Mold-loading	—	—	0.69

**Note* : In sports shoes (eg. Tennis shoes), it is customary to use sponge insole packing over the rag-insole. The sponge compound is placed in a rectangular mould over which a cloth coated on one side is placed with the coated side towards the sponge compound and cured. Sponge insole are then punched out.

MOULDED ON PROCESS FOR FOOTWEAR
(D. V. FOOTWEAR)

During the past 25 years two significant developments for higher productivity have taken place in the world of shoemaking industry :

(i) the rubber "molded-on" or Direct Vulcanization (D.V.) process and

(ii) the injection "molded-on" process.

In India the direct vulcanization process is now established in major shoe companies, while the injection molded-on process is practised only in one unit.

Besides giving higher production, the other advantages of manufacture by DV are the excellent bonding obtained between canvas and leather uppers to sole and heels, unit process operation as compared to other conventional methods of manufacture, lower labour cost and lesser rejects. These advantages out weigh the initial capital cost involved in the machinery.

It may be mentioned here that in our country as well as in America and U.K., almost all the defence footwear is made by the DV process.

THE DV PROCESS :

The canvas or leather upper (buffed on the under side) is mounted on the last, which is super-imposed over the sole-heel cavity. The rubber slug is kept in this cavity and the last lowered over it. Under the force exerted (DV presses have high operating ram forces in the range of 0 to 8000 kg) by the ram on the mould, the rubber is shaped, bonded with the canvas or leather upper and vulcanized in one operation. The whole system is semi-automatic, equipped with time-setter and temperature controllers. An operator is able to handle atleast 6 D.V. presses in series.

TYPES OF SHOES MADE BY DV PROCESS :

(a) Leather upper with solid rubber sole.

(b) Canvas-upper with solid rubber sole.

(c) Canvas-upper with sponge rubber sole with or without undertread.

COMPOUNDING SYNAPRENE RUBBERS FOR D.V. PROCESS :

The following points should be given due consideration.

(1) *Plasticity* : The compounded stocks for DV footwear should have high but controlled plasticity for perfect mold flow. For DV sponge soling the plasticity of the compound should be much higher as here there is no external pressure except that created by the blowing agent.

(2) *Curing System* : The curing system is complex. A good accelerator combination is found in a basic thiazole i.e. MBT boosted with guanidine and dithiocarbamate, activated by triethanol amine. The processing safety against scorch is achieved by incorporating a retarder.

(3) *Resistance to Reversion* : The temperature of the last is kept around 50°C to prevent damage to the upper material, while the temperature of the sole plate may be any where around 152-180°C. To compensate for the temperature difference the compound should be fast curing, so that the compound near the cooler last (50-55°C) should vulcanize and the part in contact with the hot sole-plates should not revert within the short cure-time cycle.

(4) *Rubber Cement* : For preparing rubber cement to be applied on the bottom part of the upper, a solution of the DV compound in equal proportion of Toluene: Naphtha is recommended to get excellent bond between the upper and the sole.

ADVANTAGES OF SYNAPRENE RUBBERS IN DV COMPOUNDS :

(1) High plasticity (Low Mooney) rubbers are preferred for DV footwear compound because the compounded-mooney of the stock should be sufficiently low. Synaprene 1513 is an ideal grade from this view point. Critical control of the viscosity is easier with Synaprene rubbers.

(2) Synaprene rubber compounds maintain the shape and dimension of the preforms under storage. The preforms do not exhibit cold flow because of controlled plasticity.

(3) Synaprene 1958 imparts very high resistance to abrasion, improves mold flow and gloss of the finished product, increases hardness and yet maintains low specific gravity of the stock.

(4) Synaprene rubbers take up higher dosages of processing oils for economic compounding.

(5) Synaprene rubbers are inherently reversion resistant.

D. V. SOLES FOR LEATHER UPPERS

	Coloured	**Black**	**Red**
	1	2	3
Synaprene-1502/1513	45	65	40
Synaprene-1958	15	15	15
RMA-IX	40	20	30
Red. Reclaim	—	—	30
WTR	—	15	—
Cal. silicate	20	—	20
Light $MgCO_3$	20	—	20
China clay	40	30	40
HAF	—	30	—
Cumar	5	5	5
Naph. oil	10	10	10
ZnO	4	4	4
St. acid	1.5	1.5	1.5
A.O. SP	1.5	—	1.5
A.O. PBN	—	1	—
A.O. PBN & DPPD	—	1	—
MBT	1.0	1.0	1.0
DPG	0.75	0.75	0.75
ZDC	0.50	0.50	0.50
TEA	2.0	2.0	2.0
Sulfur	2.0	2.0	2.0
NDPA	0.3	0.3	0.3
TiO_2 & Colour	qs	—	qs
S.G.	1.26	1.20	1.25
ML4	45	42	46
D.V. Cure	7'	8'	8'
Mould Temp. °C.	150	153	150
Last Temp. °C.	50	40	50
T.S.	178	165	151
% E.B.	450	450	425
Hardness	63	68	66
Flex 1*	410	320	286
Abr. loss	1.67	2.16	2.68

*For 500% cut growth.

D. V. CANVAS SOLES

Synaprene-1513	70
RMA-IX	30
Cal. Silicate	20
Hard clay	50
Whiting	50
Naph. oil	10
Cumar	5
Zinc oxide	4
St. acid	1
A.O. SP	1
P. Wax	0.5
CBS	1.4
DPG	0.25
TMTD	0.25
TEA	1.0
Sulfur	2.4
TiO_2 & Colour	qs
S.G.	1.43
D. V. Cure	4'
Mould Temp. °C	150
Last Temp. °C	120

NITRILE RUBBERS

Acrylonitrile-butadiene rubbers (NBR) are special purpose copolymers used whenever oil resistance is desired.

There are about 5 variables in dry nitrile rubbers, they being (i) Acrylonitrile content (ii) Product stain (iii) Mooney viscosity (iv) Polymerization Temperature and (v) Vinyl Chloride content. An appropriate manufacturing change in any of the above factors can give the TYPE of Nitrile rubber required.

Besides the above main aspects of variables and rubber designations, at present, Nitrile rubbers are also available as (1) Carboxylated elastomers (2) Powder form (3) Crumb form-gelfree (4) Liquid rubbers (5) Copolymers of Acrylonitrile and Isoprene (6) Copolymers of Styrene-acrylonitrile and (7) DOP extended elastomers.

Powdered NBR and NBR/PVC Blends are now commercially available. In place of mill-mixing powdered rubbers could be easily dry-mixed by using extruder, giving adequate passes. Injection moulding could be also carried out by employing powder technology. Recent papers and other literature also indicate the utility of powdered SBR in a similar manner.

Nitrile latices having low to high acrylonitrile content of 40 to 60 percent total solids, having varied viscosity range, carboxylated modification styrene modification, are available for varied use, such as textile, leather and paper industry. Each year finds the addition of some newly developed nitrile rubbers for specific properties.

(I) ACRYLONITRILE CONTENT : This is the prime factor which governs the service property of the rubber product. Nitrile rubbers are made with an Acrylonitrile content (wt%) ranging from low to ultra-high. Typical properties with respect to variation in nitrile content are given below.

High Nitrile Content	*Property*	*Low Nitrile Content*
High	Solubility in ketones and esters (uncured)	Low
Low	Solubility in aromatic solvents (uncured)	High
High	Solvent and oil resistance	Low
Low	Gas impermeability	High
Low	Resilience	High
Low	Low temp. flexibility	High
High	Resistance to ozone	Low
High	Cost	Low

(II) PRODUCT STAIN : During manufacture of the copolymer antioxidants added may be of the staining type (amines) or of the non-staining (phenolics) giving rise to the product characteristics of staining, slightly staining or non staining types.

(III) MOONEY VISCOSITY : As in SBR, Nitrile rubbers are made in a range of mooney viscosities to facilitate processing and product manufacture. The ML4 ranges from 30 to 140 for different types.

(IV) POLYMERIZATION TEMPERATURE : Manufacture of nitrile rubbers by emulsion polymerization is on similar lines as SBR. The 'Hot' polymerization temperature ranges from 30-50°C while the 'Cold' polymerization temperature is around 5°C. The older 'Hot' type of rubbers generally require mastication to render them soluble. The newer easy-processing highly modified 'Cold' types of rubber will dissolve easily to give solutions of low viscosity. The 'Cold' types have better sulfur disperion and lower black incorporation time (B.I.T.)

(V) VINYL CHLORIDE CONTENT : Nitrile rubbers are more susceptible to ozone attack, than other general purpose or special purpose polymers like polychloroprene or fluoro elastomers. To offset this disadvantage recourse can be had to (1) using suitable antiozonants and (2) during the manufacturing stage nitrile latices are blended with vinyl resins (PVC) and completely mixed to form a homogenous product. The second methods is preferable. Dry blending with PVC in the banbury (fluxing at 160°C) is also done when such vinyl modified nitrile rubbers are not available. It is observed that such blends are superior, in most of the properties, to both Neoprene and Nitrile rubbers and yet are lower in cost. A blend of 70/30 with a medium acrylonitrile content rubber to PVC, gives optimum results.

STATUS OF NITRILE RUBBER AS AN OIL RESISTANT RUBBER

There are a number of oil resistant polymers, which are presently being used as per the end-application requirement. The following table shows the status of nitrile rubber as an oil resistant polymer in comparison with the newly developed oil resistant rubbers.

Comparative properties of some oil resisting polymers

	Low % ACN	High % ACN	Epichlorohydrin I*	Epichlorohydrin II*	Copolymer of chloroprene & ACN	Polyacrylate
Processability (Mill mixing)	—	—	3	3—4	2	4
Curing properties	—	—	3—4	3	2	4

Tensile strength (RT)	2	1	3	3	1	4
Properties, temp. dependant (TS, EB, Hardness)	2	3	3	1	4	4
Low. temp. flexibility	1	3	3	1	4	4
Rebound	1	3	4	2	4	4
Permanent set	—	—	2	2	4	3
Abrasion resistance	2	1A	3—4	3	1	4
Heat resistance	3	2	2	2	2	1
Stress relaxation	1A	1	2	2	4	1
Compression set	1A	1	3	3	4	4
Oil resistance (a) Drop in Physicals	4	1	1	1	1	1
(b) Volume change △ V	4	1	1	1	3	2
Fuel oil resistance △ V	4	1	1	1	3	4
Ozone resistance	4	2	1	1	1	1
Water absorption △ V	—	—	2	3	2	4
Metal corrosion	—	—	3	4	3	2

1A = Out standing; 1 = Excellent; 2 = Good; 3 = Fair; 4 = Poor.

* Epichlorohydrine homopolymer.
Epichlorohydrine ethyleneoxide copolymer.

It will be seen from the table that Epichlorohydrin II has a few advantages over Epichlorohydrin I in respect to low temperature properties and other temperature dependent properties. In comparison with low ACN content nitrile rubbers, Epichlorohydrin II is much superior in oil resistance, however, high ACN content nitrile rubber is superior for tensile strength at room temperature, abrasion resistance, stress-relaxation and compression set. Polyacrylates excel in high temperature resistance for sulfur bearing oils.

It may be thus seen that nitrile rubbers still retain their present status as the main oil resistant rubber, and the other polymers may suitably supplement it whenever their properties may effectively replace the deficiencies of nitrile rubber.

BLENDS OF ACRYLONITRILE RUBBER WITH SYNAPRENE RUBBERS

Acrylonitrile rubbers (NBR) are used primarily for their oil resistance at both low as well as high temperatures. The availability of imported acrylonitrile rubbers in India is restricted. Synaprene rubbers are useful extenders for these rubbers and have better advantages over natural rubber. Natural rubber differs very much in polarity from NBR and hence its compatibility with NBR is limited. Cure characteristics of natural rubber differ from those of NBR. Natural rubber has poor oil-swell resistance as well as poor resistance to ageing at high temperatures. Addition of natural rubber to NBR is done only for the purpose of improvement of tack and low temperature properties and is restricted to the extent of 10-20%.

Synaprene rubbers, on the other hand, have solubility parameter nearer to that of NBR giving better compatibility with NBR. Cure characteristics of both rubbers are identical and both rubbers have good resistance to abrasion. Synaprene rubbers have oil swell resistance superior to that of natural rubber.

When Synaprene rubbers are blended with NBR in any proportions, there is hardly any serious effect on the physical properties like tensile strength, elongation at break, modulus, hardness and compression set. But oil resistance of the NBR compounds is reduced proportionately. However it is possible to use a blend of high acrylonitrile NBR, with Synaprene rubber and get the degree of oil resistance equal to that given by a low acrylonitrile NBR, with overall economy in cost. Products from high acrylonitrile NBR have a tendency to shrink in contact with hot lubricating oils. Replacement by part with Synaprene will overcome this defect.

Synaprene 1513/1514 are the best grades for the extension of SBR because of their better oil-swell resistance. However, if low temperature characteristics (below — 20°C) are desired, it is preferrable to use Synaprene EBR or EBR-OE. Synaprene 1958 also can be used in high hardness oil resistant compound, e.g. hydraulic press gaskets.

SYNAPRENE/NBR/PVC BLENDS

PVC resins are compatible with NBR. Such premixed blends of PVC-NBR are available abroad. PVC resins enhance the oil resistance and especially the ozone resistance of NBR compound. Such blends also can be further extended with Synaprene rubber. For best physical properties, it is necessary to flux PVC resin in NBR at temperature around 160°C. This can be accomplished by making PVC-NBR masterbatch in the banbury or extruding a mill-mixed masterbatch through a plastic extruder at 160°C. Synaprene rubber can then be mixed with this masterbatch. Since PVC resins enhance the oil- resistance of nitrile rubbers, the masterbatch can be extended with higher quantities of Synaprene rubbers. The ozone resistance of the blend decreases as the quantity of Synaprene is increased, but it can be improved by the use of proper antiozonants.

In the formulations that follow, the effect of addition of Synaprene to NBR is explained and also compounds to meet various ASTM (D-746) specification are also given.

BLENDS WITH VERY HIGH ACRYLONITRILE RUBBER

Base Recipe

Polymer	100	St. Acid	1
FEF	50	A.O. PBN	1
Modified P/F Resin	10	MBTS	1.5
DBP	15	TMTM	0.3
Zinc Oxide	5	Sulfur	1.5

Cure @ 152°C for 15 min.

Compd. No.	1	2	3	4	5
NBR (V. High)	100	75	50	45	30
PVC*	—	—	—	30	20
S-1514/1513	—	25	50	25	50
T.S.	184	177	178	134	134
E.B.	490	450	440	175	230
Hardness	65	64	63	81	77
Aged 70 hrs @ 100°C in air					
△ T.S.	+ 9	+10	+ 7	+31	+23
△ E.B.	—29	—25	—30	—43	—43
△ Hardness	+10	+ 9	+11	+ 7	+10
Aged 70 hrs. @ 100°C in ASTM Oil No. 1					
△ T.S.	+ 8	+ 7	+ 2	+19	+11
△ E.B.	—27	—27	—20	—32	—24
△ Hardness	+ 8	+ 8	Nil	+ 7	+ 8
△ V	—11	— 6	+ 3	— 8	+ 1
Aged 70 hrs. @ 100°C in ASTM Oil No. 3					
△ T.S.	+10	—18	—40	+ 2	+10
△ E.B.	—17	—29	—41	—20	—37
△ Hardness	— 1	— 8	—18	— 3	—14
△ V	— 1	+17	+43	+14	+41

Aged 48 hrs. @ room temperature in Petrol.					
△ T.S.	—21	—40	—54	—23	—45
△ E.B.	—14	—33	—50	—29	—52
△ Hardness	— 8	—11	—12	— 8	— 9
△ V	+10	+19	+34	+12	+31

Note : By blending Synaprene 1513/1514 with NBR (High ACN content) any desired degree of oil resistance, whether equal to that of medium acrylonitrile rubber or equal to that of polychloroprene rubber can be obtained.

*PVC used for this work is a paste grade resin having 'K' value 70.

BLENDS WITH MEDIUM HIGH ACRYLONITRILE RUBBER

Base recipe same as in blends with acrylonitrile rubber.

Compd. No.	1	2	3	4
NBR (Medium)	100	75	50	—
Synaprene-1514/1513	—	25	50	100
Original properties				
T.S.	147	172	149	186
E.B.	425	375	360	460
Hardness	59	58	59	57
Comp. Set%	9	8	12	33
Aged 70 hrs. @ 100°C in air				
△ T.S.	+ 4	— 8	+14	—11
△ E.B.	—28	—32	—19	—55
△ Hardness	+ 3	+ 5	+ 5	+10
Aged 70 hrs. @ 100°C in ASTM Oil No. 1				
△ T.S.	+ 7	—23	+ 8	—30
△ E.B.	—23	—33	—14	—37
△ Hardness	+ 5	+ 2	— 1	— 8
△ V	— 8	— 5	+ 3	+23
Aged 70 hrs @ 100°C in ASTM Oil No. 3				
△ T.S.	— 5	—37	—45	—85
△ E.B.	—24	—39	—36	—73
△ Hardness	— 5	— 8	—15	—20
△ V	+10	+28	+55	+136
Aged 48 hrs @ room temperature in Petrol				
△ T.S.	—56	—63	—59	—77
△ E.B.	—47	—49	—49	—72
△ Hardness	—10	— 9	— 9	— 7
△ V	+21	+26	+41	+76

OIL RESISTANT COMPOUNDS
ASTM BG SERIES

Compd. No.	1	2	3	4	5
	(SB) 508 BG	(SB) 605 BG	(SB) 610 BG	(SB) 615 BG	(SB) 715 BG
NBR (V. High)	70	50	—	75	60
NBR (Medium)	—	—	70	—	—
S-1514/1513	30	50	30	25	40
FEF	40	40	50	—	55
GPF	—	—	—	40	—
Hard clay	—	—	—	60	—
Soft clay	—	25	—	—	—
Pptd. $CaCO_3$	70	50	100	—	—
DBP	25	20	25	25	10
Ar. Oil	25	30	25	10	15
Cumar	10	7.5	10	10	10
Zinc oxide	5	5	5	5	5
St. acid	1	1	1	1	1
A. O. PBN	1	1	1	1	1
CBS	1.2	1.2	1.2	—	—
MBTS	—	—	—	1.5	1.5
TMTM	0.3	0.3	0.4	0.3	0.3
Sulfur	1.6	1.5	1.6	1.6	1.5
S.G.	1.3	1.3	1.36	1.3	1.15
Cure @ 152°C for 15 minutes.					
T.S.	71	73	74	122	153
E.B.	465	400	385	515	300
Hardness	48	58	56	63	68
Comp. set %	—	—	—	26	36

(Table Continued)

Aged 70 hrs. @ 100°C in air.					
△ T. S.	+ 3	— 8	— 3	+ 2	— 4
△ E.B.	—23	—32	— 9	—30	—10
△ Hardness	Nil	+ 5	+ 2	+ 4	Nil
Aged 70 hrs. @ 100°C in ASTM Oil No. 1					
△ T. S.	+ 6	+ 2	Nil	+13	+ 7
△ E.B.	—26	—55	—22	+ 31	—25
△ Hardness	+10	+ 5	+ 8	+ 6	Nil
△ V	—11	— 9	—10	— 7	— 2
Aged 70 hrs. @ 100°C in ASTM Oil No. 3					
△ T.S.	—20	—41	—19	—12	—25
△ E.B.	—21	—34	—25	—29	—32
△ Hardness	—17	—30	—17	— 6	—10
△ V	+30	+40	+22	+18	+26
Aged 48 hrs. @ room temperature in Petrol.					
△ T.S.	—35	—28	—39	—	—
△ E.B.	—19	—28	—29	—	—
△ Hardness	—11	—20	—12	—	—
△ V	+11	+16	+ 9	—	—
Aged 48 hrs. @ room temperature in ASTM Fuel B					
△ T.S.	—	—58	—57	—	—
△ E.B.	—	—40	—42	—	—
△ Hardness	—	—25	—22	—	—
△ V	+58	+49	+36	—	—

OIL RESISTANT COMPOUNDS
ASTM BC SERIES

Compd. No.	1	2	3	4	5
	(SC)	(SC)	(SC)	(SC)	(SC)
	505	605	608	708	715
	BC	BC	BC	BC	BC
NBR (V. High)	—	—	30	30	30
NBR (Medium)	50	50	—	—	—
S-1514/1513	50	50	70	70	70
FEF	20	30	25	40	—
GPF	—	—	—	—	60
Hard clay	—	—	—	—	60
Soft clay	40	—	50	50	—
Pptd. $CaCO_3$	60	135	50	80	—
Brown Factice	15	15	—	—	—
DBP	15	15	15	15	10
Cumar	10	10	5	5	5
Ar. oil	35	35	35	35	20
Zinc oxide	5	5	5	5	5
St. acid	1	1	1	1	1
A.O. PBN	1	1	1	1	1
CBS	1.2	1.2	1.25	1.25	—
MBTS	—	—	—	—	1.5
TMTM	0.5	0.5	0.3	0.4	0.3
Sulfur	2	2	2	2	1.5
S.G.	1.32	1.28	1.34	1.29	1.33
Cure @ 152°C for 15 minutes.					
T.S.	38	48	58	61	129
E.B.	450	390	425	300	360
Hardness	53	58	62	70	68
Comp. set %	—	—	—	—	36

Aged 70 hrs. @ 100°C in air					
△ T. S.	+18	— 5	— 2	Nil	+ 6
△ E. B.	—30	—27	—45	—38	—32
△ Hardness	+ 4	+ 1	+ 2	+ 2	+3
Aged 70 hrs. @ 100°C in ASTM Oil No. 1					
△ T. S.	—16	—23	+12	+3	+ 2
△ E.B.	—28	—24	—30	—35	—29
△ Hardness	+ 4	Nil	— 3	— 2	— 8
△ V	—10	— 3	— 3	— 2	+ 10
Aged 70 hrs. @ 100°C in ASTM Oil No. 3					
△ T.S.	—50	—31	—39	—39	—50
△ E.B.	—36	—23	—49	—49	—54
△ Hardness	—30	—24	—30	—35	—23
△ V	+67	+45	+75	+59	+61
Aged 48 hrs. @ room temperature in Petrol					
△ T.S.	—45	—58	—52	—51	—
△ E.B.	—17	—32	—62	—38	—
△ Hardness	—16	—15	—27	—23	—
△ V	+16	+17	+19	+19	—
Aged 48 hrs. @ room temperature in ASTM Fuel B					
△ T.S.	—66	—64	—69	—65	—
△ E.B.	—45	—49	—48	—48	—
△ Hardness	—25	—25	—33	—33	—
△ V	+60	+44	+69	+56	—

	Stabiliser Pad.	**Stabiliser Bushing**	**Grease cup Ring**
NBR (V. High)	25	25	25
Synaprene-1514	75	75	75
FEF	50	75	50
Hard clay	50	—	—
Pptd. $CaCO_3$	—	100	—
Whiting	50	—	—
Ar. oil	25	10	20
Cumar	15	15	10
Zinc oxide	5	5	5
St. acid	1.5	1.5	1.5
A.O. PBN	1	1	1
P. Wax	1.5	1.5	1.5
MBTS	1.25	1.5	1.25
TMTD	0.2	0.15	0.2
Sulfur	1.5	1.5	1.5
S.G.	1.43	1.45	1.12
Cure @ 152°C	10'	10'	10'
T.S.	71	73	110
E.B.	300	200	370
Hardness	73	84	73
Comp. Set %	—	16	—
Aged 70 hrs at 100°C in ASTM Oil. No. 1			
△ T. S.	—13	+ 4	— 6
△ E.B.	—30	—24	—24
△ Hardness	— 8	— 8	—15
△ V	+13	+13	+16

	Kerbside pump Hose	**Pressure Cooker Gasket**
NBR (High)	45	40
PVC*	25	—
Synaprene1513/1514	30	—
Synaprene-1502	—	60
FEF	15	50
Soft clay	50	—
Whiting	100	—
Ppted. $CaCO_3$	—	30
DBP	10	—
Ar. oil	10	—
P. oil	—	5
Mod. P/F Resin	10	—
Cumar	10	4
Zinc oxide	3	5
St. acid	1	1
A.O. SP	1	—
A.O. Ketone-amine	—	1.5
P. Wax	—	2
MBTS	1.5	—
TMTD	—	0.75
TETD	—	0.75
ZDC	—	0.3
Sulfur	1.5	0.5
Lead carbonate	1.25	—
S.G.	1.53	1.18
Cure @ 152°C	20'	8'
T.S.	94	148 (Nil)†
E.B.	280	325 (—28)
Hardness	83	69 (+4)

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*PVC paste grade resin, having 'K' value 70 and nitrile master-batch should be prepared and fluxed at 150°C to get highest reinforcing value.

†Results after air ageing at 120°C for 70 hrs.

BLENDS OF SYNAPRENE RUBBERS WITH POLYCHLOROPRENE RUBBERS

Synaprene rubbers can be conveniently used for the extension of polychloroprene rubbers to improve the crystallization resistance and the compression set resistance. The ozone resistance proportionately decreases but it can be brought up to the former levels by the use of antiozonants. When the low temperature properties are important Synaprene 1500 and Synaprene 1502 should be preferred while Synaprene 1513/1514 should be preferred where oil resistance is the main requirement.

It is reported that polychloroprene SBR blends have better resistance to discoloration in sunlight than polychloroprene rubbers alone.

Comp. No.	1	2	3	4	5
CR	100	75	50	75	50
Synaprene-1500	—	25	50	—	—
Synaprene-1514	—	—	—	25	50
FEF	50	50	50	50	50
Ar. oil	15	15	15	15	15
Naph. oil	15	15	15	15	15
Zinc oxide	5	5	5	5	5
St. acid	0.5	0.75	1	0.75	1
A.O. PBN	1.5	1.5	1.5	1.5	1.5
Light MgO	4	3	2	3	2
TMTM	0.5	0.75	1	0.75	1
DOTG	0.5	0.75	1	0.75	1
Sulfur	1	1.25	1.5	1.25	1.5
Cure @ 152°C for 15 minutes.					
T.S.	163	141	134	167	151
E.B.	450	452	375	400	325
Hardness	49	53	53	53	53
Comp. set %	58	49	26	50	28

Aged 70 hrs. at 100°C in air					
△ T. S.	— 4	+ 2	— 7	+ 1	+ 5
△ E.B.	—22	—27	—27	—25	+ 17
△ Hardness	+ 4	+ 5	+ 5	+ 7	+ 4
Aged 70 hrs at 100°C in ASTM Oil No. 1					
△ T. S.	— 8	+ 6	— 7	— 6	—12
△ E.B.	—31	—24	—25	—28	—23
△ Hardness	+ 6	nil	— 1	nil	— 2
△ V	— 4	—11	+ 4	+ 1	+ 5
Aged 70 hrs at 100°C in ASTM OIL No. 3					
△ T.S.	—62	—61	—63	—70	—72
△ E.B.	—41	—44	—53	—50	—54
△ Hardness	—24	—25	—22	—25	—21
△ V	+77	+93	+94	+86	+83
Aged 48 hrs at room temperature in Petrol					
△ T.S.	—53	—53	—61	—68	—73
△ E.B.	—40	—50	—53	—50	—54
△ Hardness	— 8	—10	—12	—11	—12
△ V	+24	+38	+52	+37	+42
Aged 48 hrs at room temperature in Fuel B					
△ T.S.	—76	—73	—77	—73	—83
△ E.B.	—62	—66	—67	—62	—69
△ Hardness	—14	—16	—12	—18	—15
△ V	+72	+80	+96	+78	+74

	SPECIAL HOSE *	BATTERY BOOT
CR	80	50
Synaprene-1514	20†	50
FEF	25	60
Soft clay	100	—
Whiting	—	40
Cumar	7	—
Ar. oil	—	30
Naph. oil	7	—
P. Jelly	—	2
A.O. PBN	1	1
P. Wax	1	—
DPG	0.75	0.5
TMTM	0.75	0.5
Sulfur	1	1
MgO	4	2
Zinc oxide	5	5
Ethylene Thiourea	—	0.2
S.G.	1.6	1.33
Cure @ 152°C	10'	10'
T.S.	85	126
E.B.	320	380
Hardness	71	58
Aged 70 hrs. @ 100°C in ASTM Oil No. 1		
△ T.S.	+ 5	—28
△ E.B.	—30	—26
△ Hardness	— 3	—10
△ V	+ 5.5	+15
Aged 70 hrs. @ 100°C in ASTM Oil No. 3		
△ T.S.	—26	—
△ E.B.	—39	—
△ Hardness	+ 33	—

1.20

---

*Special hose for oil suction and delivery.

†20 phr 1513 may be used in place of S-1514.

Dispersion in rubber	: Easy, uniform and fast.
Solubility	: Very freely soluble in benzene, carbon tetrachloride, methylene chloride, ethyl alcohol, ethyl acetate, acetone. Soluble in petrol, practically insoluble in water.
Handling	: As it is alkaline, should not be allowed to come into contact with skin for a long time. However in vulcanized rubber, it is believed to be harmless.
Applications	: Ebonites, battery containers, typewriter rollers, industrial rollers, solid tyres, mixes containing high proportions of reclaim cycle tyres, tyre repair materials and general moulded and mechanical goods. (As it is a staining type of accelerator, it should not be used for white or coloured products).

RELATIVE PROPER

Properties \ Elastomers	Styrene Butadiene SBR	Polybutadiene BR	Natural Rubber NR	Butyl IIR	Ethylene Propylene EPDM
Specific Gravity	0.94	0.93	0.93	0.92	0.86
Hardness range Sh 'A'	40–100	40–100	30–100	40–75	45–95
Tensile Strength: Gum	P	P	G	F	P
Reinforced	VG	G	E	G	G
Resilience	G	E–O	VG	P	F–G
Tear resistance	G	G–VG	VG	G	G
Abrasion resistance	G-VG	VG–E	G	F–G	G–VG
Impermeability to gases	G-VG	P	F	E	F
*Atmospheric ageing resistance	P–VG	F–G	P–VG	G–E	E
Oxidation resistance	G	G	G	G–E	E
Heat resistance	VG	VG	G	G–E	G–E
Compression set	G–VG	G–VG	F–G	F	P–G
Low temp. flexibility	G	E	VG	F	G
Flame resistance	P–G*	P	P–G*	P	P–G*
Acid resistance: Dilute	F–G	F–G	F–G	E	G
Concentrated	F	F–G	F	E	G
Alkali resistance	G	G	G	E	G
OIL RESISTANCE					
(1) Animal and veg. oils	F–G	F–G	P–F	E	P
(2) Aliphatic hydrocarbons	F–G	F–G	P	F	F–G
(3) Aromatic hydrocarbons	F	F	P	F	F
SOLVENT RESISTANCE					
(1) Aliphatic solvents	P	P	P	P	P
(2) Aromatic solvents	P	P	P	P	P
(3) Chlorinated solvents	P	P	P	P	P
(4) Oxygenated solvents	G	G	G	G	G
Dielectric Strength	E	E	E	E	E
Electrical Insulation	G–E	G–E	G–E	G–E	E
Adhesion to Metals	E	VG	VG	G	F

* Suitably compounded

Ratings : P — Poor, F — Fair, G — Good,

Comp

S OF ELASTOMERS

itrile NBR	Polychloroprene CR	Poly sulphide PS	Poly Urethane PU	Silicone Si.	Fluorocarbon FL	Hypalon CSPE	Polyacrylate ABR	Epichlorohydrin
.98-1.0	1.23	1.25-1.34	1.05-1.24	—	1.72-2.02	1.1	1.09-1.12	1.27-1.36
0-100	40-95	20-80	20-100	20-90	55-80	45-95	40-90	40-95
	VG	P	V	P	F	G	P	P
G	VG	F	E-O	F	VG	VG	G	G
-G	G	F-G	G-VG	F-G	P-F	G-E	P-F	F-G
-P	G	F-P	G-E	F	F-VG	F	F	F-G
-VG	E	F	E-O	F	G-E	E	F	F-G
G-E	G	E-O	F	F	G-E	G	G	VG-E
	E	E	VG	E	VG	E-O	E	E
	G	E	VG	E	E-O	E	VG	F
	E	F-G	G	E-O	E-O	E	E	G
G	P-G	P-F	G	E	F-G	F	F-G	G
	F-G	G	G	E-O	F	F	P	G
	VG	P	F-G*	F	VG	VG	P	P
	E	G	F	G	E	E	F	G
	G	P	P	P	E	E	P	F
	G	G	P	P	P	VG	F	F
	G	E	E	G	G	F	E	E
G-E	VG	E	VG-E	F-G	E	VG	G	VG-E
G	F-G	E	G-E	G	E	F-G	VG-E	VG
	G	E	E	G	E	G	G	VG-E
	F	G	F	G	E	F	P	F-G
	P	E	P	F	G	P	P	P
	P	G	P	F	P	P	P	P
	G	F	E	G	G	E	P	P
	F-G	F-G	F	E	F-G	G	P	P
	E	P	-	P	—	VG	-	-

G — Very Good.   E — Excellent,   O — Outstanding

l Data

RELATIVE GAS PERMEABILITY OF SOME VULCANIZED ELASTOMERS*

Elastomers	Air	O2	H2	He	CO2	N2
Natural rubber	100	100	100	100	100	100
Synaprene-1500	65	74	18	76	72	60
Synaprene 1513/1514	21	25	6	25	24	20
Synaprene-1712	70	80	25	80	78	65
Synaprene-EBR-OE	228	258	63	265	252	210
Polychloroprene (Mercaptan modified)	23	16	3.6	15	15	12
Nitrile (Low% ACN)	21.7	24.5	6	25	24	20
Nitrile (Medium % ACN)	9.7	11	—	11.4	10.8	9
Nitrile (High % ACN)	5.4	6.2	—	6.3	6	5
Nitrile/PVC (70:30)	3.25	3.7	—	3.8	3.6	3
Butyl	3.25	3.7	—	3.8	3.6	3
Polysulphide	—	1.2	3.2	—	2.4	—

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* @ 50 phr HAF Loading.

SYNAPRENE S-2000 LATEX

Synaprene S-2000 latex is a co-polymer latex of Styrene and Butadiene manufactured by a hot emulsion polymerisation system. This special latex, having fine particle size, is developed for tyre cord dippings.

SPECIFICATIONS

(Tentative)

Properties	*Min.*	*Max.*	*Typical*
Total Solids %	40	44	42.6
Bound Styrene %	44	48	45.2
Residual Styrene %	—	0.1	—
ML_4 of Solids	60	90	72
Surface Tension dynes/cm @ 25°C	47	53	49.4
pH	10.5	11.5	10.75
Sp. Gravity of Latex 25°C/25°C	—	—	0.99

APPLICATION: A versatile latex for tyre cord dipping. May be used for compounding adhesives for footwear and paper industry. Other applications are upholstery, and carpet backings, paper and board saturation and linings for proofed goods like fire-fighting hoses, etc.

CORD DIP

TABLE I
RESIN MASTER

	Dry Parts/100 RHC
Resorcinol	11
Formaldehyde (40%)	6
Sodium Hydroxide (10%)	0.3
	17.3
Total Solids %	5
pH	7 to 7.5

TABLE II
Final Dip Composition

	For Rayon Dry Parts	*For Nylon* Dry Parts
Resin Master	17.3	17.3
Vinyl Pyridine Latex (15% VP)	20	80
Synaprene S-2000 Latex	80	20
Ammonium Hydroxide (30%)	q.s. for pH 8 to 8.5	q.s. for pH 10 to 10.5
Total Solids %	12	20

NOTES : (1) Additional water may be carefully added to get the above-mentioned percent solids at both the steps.

(2) Resin master may be ripened for 2 to 6 hours @ RT or below.

(3) Final dip composition may be aged for one day prior to use.

(4) Pot life of final dip composition is very limited, hence careful handling is expected.

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Page No.	Line	Incorrect	Correct
1	17	afforts	efforts
Banbury Power Study	In Fig. 1, & Fig. 2	kwh	KW
74	7	reinforced	reinforces
93	sub title	Passanger	Passenger
93	last line	compd. 5 has	compd. 5 for
101	18	elimintaes	eliminates
143	18	preperred	preferred
189	2	resistance oxidative	resistance to oxidative
189	4	ands 1514	and S-1514
208	3	for compd 1 and 2 — —	for compd. 1 and 2 60.0 60.0
249	above column 'B'	—	phr
	above column 'C'	—	S.G.
	above column 'D'	—	Rs./kg.
	above column 'E'	—	Total Cost