THE EFFECT OF VARIABILITY OF RUBBER ON VULCANISATION*

BY

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Summary

The foreword gives a brief history of the exploration of the variability of plantation rubber by vulcanisation testing.

Until recently, vulcanisation testing in the producing countries was carried out almost exclusively on simple rubber-sulphur mixes. The results of such tests are discussed in the light of the argument that they can be of little value to the consumer, since the testing mixes bear little relation to compounds in common trade use.

The testing formula approved by the Rubber Division of the American Chemical Society, and the old rubber-sulphur mix have both been used as a basis of comparison of a series of plantation rubbers in order to test the degree of parallelism of the old and the new techniques. The two testing recipes give results which are more similar than might have been expected from the strength of the criticism of the simple mixes by rubber technologists.

Some examples are given of the extent of the natural variability due to special causes, notably tapping systems, and this variability is compared with that introduced by the producer during preparation.

Introduction

When Charles Goodyear was carrying out his early experiments in 1839 with the process subsequently described as vulcanisation, he could scarcely have realised in the wildest flights of imagination how vast and widespread the rubber industry was to become. Nor is it likely that he could have imagined that one hundred years later a great congress of scientists and business men would be gathered together to do honour to his name, and that his discovery would have so many facets for interesting discussion. To him one sample of wild rubber must have appeared similar to another and he would have found it difficult to believe that one day millions of acres of Hevea Braziliensis in the East would be supplying almost exclusively the raw rubber needs of the world. But so it is and with the growth of this vast industry have come inevitable problems which the consumer has to face, not least of which is the problem of the variation in behaviour of plantation raw rubber on vulcanisation.

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Since 1910 when plantation rubber first began to appear in quantity the consumer has found difficulty in handling different consignments and has constantly complained of its variable vulcanising properties. At the fourth International Rubber Conference held in London in a paper on the advantages and defects of plantation rubber Williams (1914) appealed for efforts to be made by the plantations to produce a more uniform rubber and stated that the

> "average plantation rubber as turned out today was not equal to Para in uniformity or strength. In Para the washing loss was practically constant. Vulcanisation does not present any material difficulties to the manufacturer. The same could not be said of plantation rubber."

At that time the plantation industry was producing approximately 45 per cent of the world's total production, whilst in 1938 it produced nearly 97 per cent of a total production more than seven times that of 1913, and although plantation rubber has almost entirely replaced Para, Williams' observations on the difficulties caused by the variability of its vulcanising properties are equally applicable today. Twenty four years later presenting a paper at the Rubber Technology Conference, London, Heywood (1938) describes experiments indicating difficulties which variation can cause the consumer and concludes

> "It seems clear that this series of experiments has proved that the variation which is apparent in raw rubber is still apparent in the finished tyre."

and again later

> "One can easily see from the results obtained the necessity for testing all rubbers received and of blending to obtain a uniform raw rubber with which to commence compounding."

In view of these statements it might appear that little progress has been made during the last twenty four years toward the fulfilment of consumers' wishes. Although uniform raw rubber is unfortunately not readily available, the plantation industry has not been indifferent to the consumers' requirements. From the earliest days continual and patient research work has been carried out by scientists working on behalf of the producers to investigate the underlying causes of variation in the vulcanising properties of plantation rubber. As a result of this work, which has been carried out mainly in the producing countries, a great deal of information has been gathered on the problem and improvements in the methods of preparation have taken place.

Deliberate alteration in the methods of preparation of plantation rubber will usually react on the vulcanising properties. A fairly complete understanding of the influence of the treatments used in the preparation of the usual types of rubber, sheet and crepe, has been obtained by the researches of Eaton and his co-workers in Malaya (Eaton and Grantham (1915) (1916); Eaton, Grantham and Day (1918)), and by de Vries (1920) and his collaborators in Java. It is largely as a result of their work that the methods of preparation now used on the plantations are more closely controlled than in the early days.

The work carried out by these investigators also indicated that variability was not caused entirely by methods of preparation and that inherent differences in the latex played a part; variation should be considered therefore as arising from both controllable and uncontrollable causes. Controllable causes depend almost entirely on estate factory procedure whilst uncontrollable causes are natural factors such as genetic strain, age and condition of the trees from which the latex is obtained, types of soil, climatic and seasonal changes. Tapping systems and methods of soil treatment, notably manuring, are also not entirely controllable being often dependent on market and other economic considerations.

In this paper it is proposed to confine attention to the effect of variation in vulcanising properties of No. 1 sheet because it is in this form that the consumer uses the major part of his requirements and moreover variability in first quality crepe is less than in sheet.

Extent of Variability

In 1924 the Dutch workers in Java adopted a standard of normality for the vulcanising properties of raw rubber. A sample was defined as "normal" if the time of vulcanisation required to reach a fixed state of cure in a rubber sulphur mix was within ±20 per cent of the average, and defined as "uniform" if within ±10 per cent. During the period 1921—1923 de Vries tested many estate samples of sheet and reported (1924) that 60 per cent were "uniform" and 90 per cent "normal," whilst Riebl (1929) found from an examination of a number of samples of smoked sheet received from various estates in Java that 87 per cent were "uniform" and 90 per cent "normal." Eaton and Bishop (1927) and Bishop and Fullerton (1932) examined samples of estate smoked sheet and concluded that there was a high degree of variation in the vulcanising properties. In the above investigations a simple rubber sulphur mix was used with which to compare the vulcanising properties, although work with this type of mix has been criticised on the grounds that it is not used in practice and conclusions drawn from its use are not necessarily the same as those obtained in an accelerator mix.

The rubber producers' research organisations continue to work on this problem of variability and an investigation has recently been carried out at the Rubber Research Institute of Malaya to obtain information as to the extent of variation which still occurs in plantation rubber. Smoked sheet was obtained from 157 European owned plantations in various parts of the country in response to a request for samples of their standard No. 1 product. All rubbers were prepared on or about the same day and seasonal

TABLE I

Distribution of Estates

State or Settlement	Total planted acreage*	Estates Participating in Examination		
		Number	Planted acreage	Percentage of total planted
Federated Malay States				
Perak	307,345	16	30,265	10
Selangor	351,841	27	45,374	28
Negri Sembilan	283,102	27	72,138	26
Pahang	91,138	12	22,986	25
Straits Settlements				
Singapore, Malacca, Penang	207,790	7	28,700	20
Unfederated Malay States				
Johore	523,145	39	122,412	23
Kedah	208,652	29	82,894	35
Kelantan	32,542	—	—	—
Perlis	1,674	—	—	—
Trengganu	13,153	—	—	—
Brunei	5,966	—	—	—
Total ...	2,026,348	157	404,770	20

*Does not include Small-holdings.

effects were thereby eliminated as far as possible. Table I gives the distribution of the estates, their acreage and percentage of the total planted estate acreage of Malaya, from which it will be seen that the samples examined are from widely distributed estates comprising a fifth of the total acreage and can therefore be regarded as reasonably representative of No. 1 sheet now being produced by Malayan plantations.

The samples were mixed in a rubber sulphur (100 : 10) mix, cured for 120 minutes at 148°C in an open steam vulcaniser and Schopper rings pulled on the Schopper tensile strength tester. The usual 24 hour cycle between mixing, curing and testing was observed. As a result of the excellent work of the Crude Rubber

TABLE II

Distribution of Moduli in "Captax" and Rubber-Sulphur Mixes

CAPTAX MIX			RUBBER-SULPHUR MIX		
Modulus at 700 per cent Elong kg/sq. mm.	Number of Estates	Percentage of total number	Modulus at 800 per cent Elong kg./sq. mm.	Number of Estates	Percentage of total number
0.39	20	13	0.39	13	8
0.40—0.49	59	60 (0.40—0.59)	0.40—0.49	25	
0.50—0.59	36		0.50—0.59	44	60 (0.40—0.69)
0.60—0.69	29		0.60—0.69	25	
0.70—0.79	9	27 (0.60—0.99)	0.70—0.79	15	
0.80—0.89	1		0.80—0.89	8	
0.90—0.99	3		0.90—0.99	5	
			1.00—1.09	4	
			1.10—1.19	7	32 (0.70—1.50)
			1.20—1.29	4	
			1.30—1.39	2	
			1.40—1.49	4	
			1.50	1	

Mean modulus for all samples:—

Captax	0.52 kg/sq. mm.
Rubber-Sulphur	0.67 kg/sq. mm.

Committee of the American Chemical Society a standard formula for an accelerator mix has been evolved and is now widely adopted. In addition to the rubber sulphur mix this standard "Captax" mix was used in the examination of the samples.

Rubber	100
Sulphur	3.5
Zinc oxide	6.0
Stearic Acid	0.5
Mercapto-benzothiazole ...	0.5

Mixes were cured for 40, 60, 80 and 100 minutes at 127°C and rings pulled on the Schopper. For the purpose of this paper it is not necessary to give complete modulus and tensile figures and Table II gives the distribution of the samples classified according to the modulus figures taken at 800 per cent for the rubber sulphur cures and at 700 per cent elongation for the 60 minute "Captax" cures.

These results indicate that there is considerable variation in the vulcanising properties of these samples and this is more readily seen from the distribution histograms of Figure 1.

Comparison of rubber-sulphur and Captax mixes

At first sight it appears that the rubbers are considerably more variable in the rubber sulphur mix than in the "Captax," but this is not necessarily the case as consideration of the interpretation which must be given to the modulus figures in the rubber sulphur mix will show. The usual method of reporting vulcanisation results in this type of mix is in terms of time of vulcanisation required to reach maximum tensile strength, but unfortunately the time and number of observations involved in the examination of these samples has made it impossible to report at the moment the variation in this manner. However as Wiltshire (11) points out, determination of tensile modulus at a fixed elongation and time of cure permits comparison within a series of samples and enables a prediction of the time of cure necessary for maximum tensile strength to be made with reasonable accuracy. This can only be done however when the relationship between time of cure and modulus has been well established for the methods of testing used in a particular laboratory. Moreover the straight line relationship between modulus and time of cure which is evident over a fairly wide range does not hold when the modulus is high. Data on the relationship between the time of cure and the range of modulus which occurs among these samples was not available in this laboratory and it was not possible to predict and report the time of cure of all samples from the modulus figures. It is therefore likely that the range of moduli

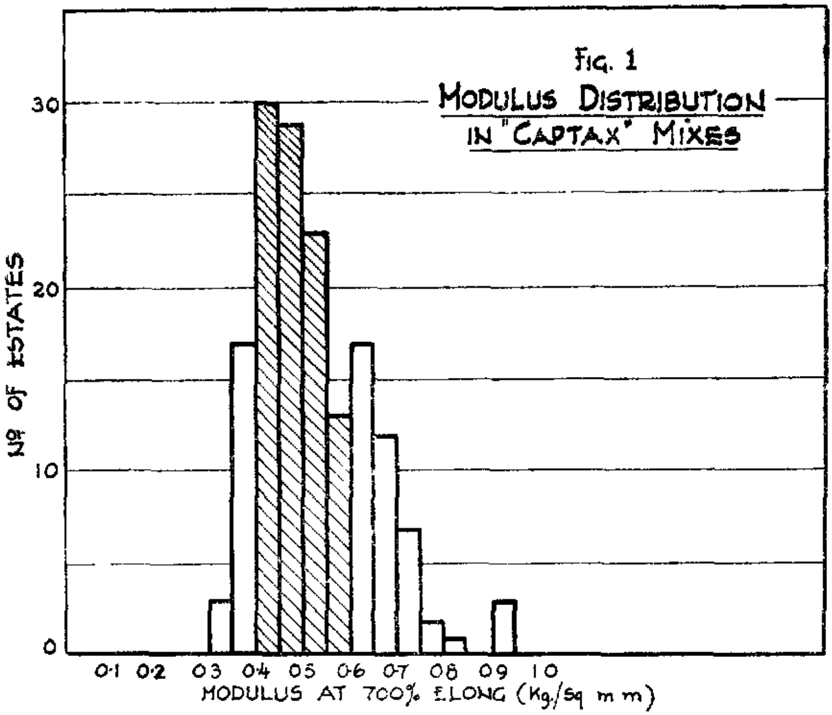
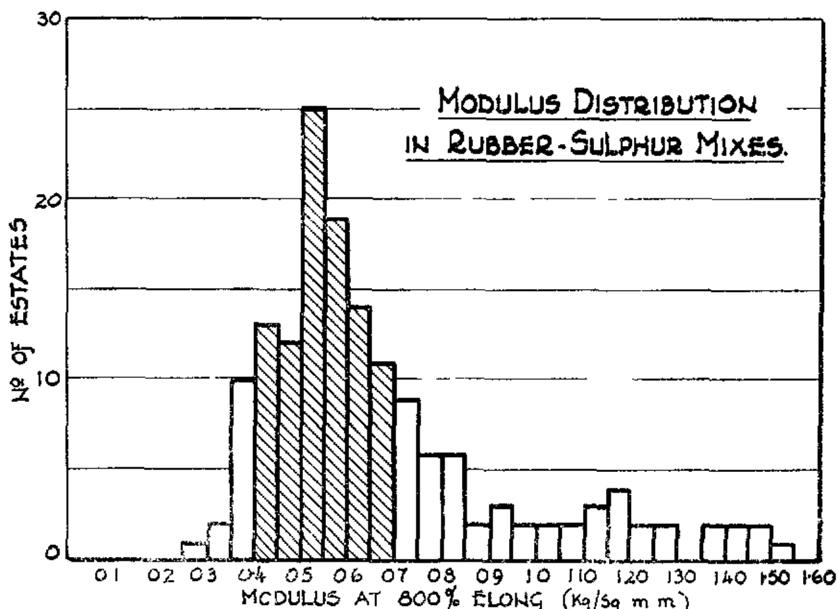


Fig. 1
Modulus Distribution
in "Captax" Mixes
No of Estates
30
20
10
0
0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1·0
Modulus at 700% Elong (Kg./Sq m m)


Modulus Distribution
in Rubber-Sulphur Mixes.
No of Estates
30
20
10
0
0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1·0 1·10 1·20 1·30 1·40 1·50 1·60
Modulus at 800% Elong (Kg/Sq m m)

shown in Figure 1 indicates a bigger variation among the samples, particularly among the faster curing samples, than would be indicated by a time-of-cure distribution. *Sixty per cent of the rubbers have modulus figures at 800 per cent elongation which lie between 0.40 and 0.69 kg/sq.mm. (inclusive) in the rubber-sulphur mix.* These modulus figures correspond to 135 and 165 minutes approximately in time of cure for which region the straight line relationship is applicable.

In view of the criticisms which have been made from time to time against the use of the rubber-sulphur mix it is of particular interest to compare the results of testing these estate rubbers in the "Captax" and rubber-sulphur formulae. Table II indicates that 20 samples when tested in the "Captax" stock had moduli less than 0.40 kg/sq.mm., 95 between 0.40 and 0.59 (inclusive) and 42 greater than 0.59 kg/sq.mm., whilst in rubber sulphur 13 were less than 0.40 kg/sq.mm., 94 between 0.40 and 0.69 (inclusive) and 50 greater than 0.69 kg/sq.mm. The modulus ranges 0.40—0.59 (inclusive) and 0.40—0.69 (inclusive) kg/sq.mm. for the "Captax" and rubber-sulphur mixes, containing 95 and 94 estates respectively, have been marked in the histograms of Figure 1 by shading, and as mentioned above they account for 60 per cent of the total number of estates. The results of the tests of the individual samples in both mixes were therefore compared in order to see if those which were in the lower, middle and higher classes when

TABLE III

Rubber-sulphur Captax Comparisons

Rubber-Sulphur Mixes		"Captax" Mixes Modulus Class and Number of Estates			
Modulus Class kg/sq.mm.	No. of Estates	Lower 0.40 kg/sq.mm.	Middle 0.40—0.59 kg/sq.mm.	Higher 0.59 kg/sq.mm.	Total Number
Lower 0.40	13	10	3	—	13
Middle 0.40—0.69	94	10	78	6	94
Higher 0.69	50	—	14	36	50
	157	20	95	42	157

tested in the "Captax" mix were in similar grades in the rubber-sulphur classification. The results are shown in Table III and indicate a good correlation. In no instance has a sample found to be in the lower or higher class when tested in rubber-sulphur appeared in the reverse order in the "Captax" mix, and although the correlation is not perfect it would appear that the information obtained by the use of a pure gum mix is not in conflict with that given by the accelerator type.

REDUCTION OF VARIABILITY BY BLENDING

The consumer frequently has to contend with variation similar to that described above, and he attempts to achieve uniformity for the vulcanising processes by blending rubbers from various consignments before compounding. It is therefore interesting to obtain from the data an estimate of the number of samples taken at random from among those tested which would be required for blending, in equal proportions, in order to obtain reasonable likelihood (95 per cent probability) that the vulcanising properties of the blend would fall within a specified range. An attempt has been made to do this from the modulus results in the Captax mix. The shaded part of the histogram, in which lie 60 per cent of the samples, with moduli between 0.4 and 0.59 kg/sq.mm. (inclusive), was selected for the specified range. It has been assumed that the modulus of a mixture of equal amounts of different samples will be equal to the mean of the moduli of the individual samples, an assumption which is approximately true in Captax mixes. The distribution of moduli of single samples is skew, (Figure 1), but if the number blended be sufficiently large the mean modulus will tend to be distributed normally, and calculations based on normal statistical theory may serve to estimate a first approximation to the number of samples required. With a mean at 0.52, 95 per cent of normally distributed variates will fall in the range 0.40 to 0.59 (inclusive), the specified limits, when the standard deviation is 4.23. Since the standard deviation of the Captax moduli for individual samples is 12.27, the number which would need to be blended to give a mean modulus with a standard deviation of 4.23 is $(12.27/4.23)^2 = 8.4$.

Causes of Variability

CONTROLLABLE VARIATION

The researches of the earlier workers on the causes of variability have shown that the rate of vulcanisation will be affected by changes in the process of manufacture which will alter the ratio of certain non-rubber substances to rubber present in the final product. Part of the non-rubber substances are present in the serum of the latex and any variation in the method of manufacture which affects the amount present in the sheet will almost certainly produce a corresponding effect on the vulcanising properties. In the early days of the plantation industry methods of manufacture varied considerably, and in spite of the continued efforts of the research organisations in the East to achieve uniformity by advising a standard procedure, variation still exists although it is now much less than before. The following brief consideration of some of the various stages in the preparation of sheet rubber will indicate that although they do have an effect on the general problem of variability it is not so great as might be supposed.

De Vries' investigations (1920) indicated that the composition of the latex may have a marked effect, for example rubbers from trees of different ages behave differently on vulcanisation, and he indicated the necessity of minimising these effects as far as possible by mixing the latex before manufacture. This has been recognised by the plantations and the majority today have facilities for *bulking* a large proportion, if not all, of their crop, but as Sackett has shown (1934) there appears to be a reasonable limit to the size of the bulking used beyond which no improvement in uniformity is obtained.

Under the present marketing system the producer is usually compelled to pay particular attention to the appearance of his sheet in order to obtain full market price. On many estates, particularly at certain times of the year, an *anti-coagulant* must be used in the field or the factory in order that sheet of finer appearance can be produced. Several chemicals have been used for this purpose in the past, but only sodium sulphite and ammonia are now generally used on the plantations in Malaya. Sodium sulphite has been found to have a slight accelerating effect whilst, according to more recent work with accelerator mixes, the use of ammonia was found by Sackett (1934) to accelerate the rate of vulcanisation, and by Bocquet (1938) to retard it when used in quantities requiring extra acid for coagulation.

The *nature of the coagulant and the amount used* have been found to affect the vulcanising properties in a rubber-sulphur mix and the following comparison of tests in "Captax" and rubber-sulphur mixes indicates the influence of excessive amounts of coagulant. A series of smoked sheets was prepared from a single bulk of latex by coagulating with formic, acetic and sulphuric acids using amounts normally recommended and multiples of these quantities. The sheets were given identical preparation treatment and when dry were vulcanised in "Captax" and rubber-sulphur mixes for 60 and 120 minutes at 127° and 148°C respectively. The

TABLE IV

Effect of Coagulant and amount used for Coagulation on the Vulcanising Properties of Smoked Sheet

Mix used	Amount of Coagulant used	Modulus In Captax at 700 per cent. Elong. In Rubber-Sulphur at 800 per cent Elong.			Tensile Strength kg/sq. mm.			Elong. at Break per cent		
		Formic Acid	Acetic Acid	Sulphuric Acid	Formic Acid	Acetic Acid	Sulphuric Acid	Formic Acid	Acetic Acid	Sulphuric Acid
" Captax "	Normal	0.52	0.51	0.57	1.39	1.38	1.74	903	900	920
	2 × Normal	0.47	0.49	0.57	1.25	1.31	1.51	898	900	899
	4 × Normal	0.43	0.47	0.53	1.29	1.24	1.39	919	908	896
	6 × Normal	0.66	0.49	—	1.69	1.34	—	883	906	—
Rubber-Sulphur	Normal	0.65	0.66	0.45	1.39	1.40	1.27	942	940	982
	2 × Normal	0.50	0.57	0.27	1.35	1.24	0.95	977	946	1034
	4 × Normal	0.44	0.51	0.22	1.20	1.25	0.79	985	973	1053
	6 × Normal	0.67	0.48	—	1.39	1.20	—	924	974	—

results, shown in Table IV, indicate that increased amounts of acid generally cause retardation but also that the use of acid in an amount far in excess of that normally required does not produce a big variation. The rubber sulphur mixing shows the well-known retarding influence of sulphuric acid which is not, however, shown in the "Captax" mix. Malayan producers have been advised not to use sulphuric acid as a coagulant; a recent questionnaire indicated that approximately 90 per cent are now using formic acid.

The variation which may arise from different amounts of *rolling and washing of the coagulum,* particularly the rolling, and from different draining and drying treatments of the wet sheet, is likely to be greater than that caused by a variation in the amount of acid used for coagulation, because these processes still vary considerably among estates. Eaton and de Vries have shown that the *dilution at which the latex is coagulated* has an effect on the vulcanisation properties in a rubber-sulphur mix and Sackett has confirmed their findings in a "Captax" mix, but dilution has little effect in modern estate practice because the producer is compelled to keep within fairly narrow limits in order to produce sheet of good appearance, and if the subsequent rolling of the coagulum and drying of the sheet were more uniform among estates it is doubtful whether it would markedly influence variability.

The amount of washing which the coagulum is given during the rolling process and the subsequent soaking of the wet sheet have also been found by the earlier workers to affect the vulcanisation; this might be expected from the generalisation that any treatment which tends to alter the ratio of non-rubber substances to rubber is likely to alter the rate of vulcanisation. There are very few estates preparing sheet rubber in Malaya today which soak their wet sheet but there are many who have a water supply which is poor and it is therefore of some interest to ascertain how much variation this would produce. Table V gives the results of vulcanising sheets prepared from a single bulk of latex by identical treatment except for the amount of washing and soaking the coagulum has received during and after rolling. Drying was carried out in a smoke-house at a temperature of 125—135°F and in a hot air cupboard thermostatically maintained at 140°F. The modulus figures indicate a slight retardation owing to the soaking of the wet sheet, but the amount of water used during the sheeting process does not appear to have affected the vulcanising properties.

The *conditions of drying* also have an influence and in general *smoking* has a tendency to retard the rate of cure; different investigators have found however widely divergent results attributable to smoking and de Vries (1920), remarks in his book that more work is required before the effect of smoking on rate of

TABLE V

Effect on Vulcanising Properties of Washing during Preparation

Washing Treatment of Coagulum	Drying Treatment of Wet Sheet			700 per cent Modulus kg/sq. mm.	T. S. kg/sq. mm.	Elongation per cent	800 per cent Modulus kg/sq. mm.	T. S. kg/sq. mm.	Elongation per cent
	Hot Air or Smoke	Temperature °F	Time Days						
No water on machines; No Soaking	Smoke	125—135	4	0.41	1.28	927	0.44	1.21	986
Full water on machines; No Soaking	,,	,,	,,	0.42	1.26	916	0.46	1.33	1000
Full water on machines; Two hours' soaking in running water	,,	,,	,,	0.35	1.01	911	0.41	1.05	977
No water on machines; No Soaking	Hot Air	140	3	0.43	1.31	905	0.62	1.42	953
Full water on machines; No Soaking	,,	,,	,,	0.43	1.35	917	0.62	1.46	955
Full water on machines; Two hours' soaking in running water	,,	,,	,,	0.35	1.14	929	0.53	1.40	979
Full water on machines; No Soaking	Hot Air	140	4	0.44	1.40	920	0.67	1.44	943
,,	,,	,,	,,	0.43	1.35	916	0.66	1.39	937

cure is understood in all its details. Investigations, of which the results will be published shortly, have been in progress at the Rubber Research Institute on the effect of the drying conditions on the vulcanising and ageing properties of sheet rubber. They indicate that this stage of preparation is of importance and does undoubtedly contribute towards variability. The temperature at which the drying is carried out appears to have a slight but noticeable effect on the rate of cure even when the drying is rapid whilst the degree of smoking which the sheet receives also has an appreciable effect. The results shown in Table VI are indicative of the effect which the conditions of drying of the wet sheet may have on the vulcanising properties of the dry rubber. A series of sheets was prepared from a single bulk of latex by identical treatment up to the drying stage, and they were then taken to various estates near the Rubber Research Institute and dried together with the estates' standard sheet. The time required to complete the drying varied in the different smoke-houses but there is no apparent correlation between the period of drying and the vulcanising properties.

TABLE VI

Effect on Vulcanising Properties of Drying Conditions

Where Dried	CAPTAX MIX			RUBBER-SULPHUR MIX		
	700 per cent Modulus kg/sq. mm.	T. S. kg/sq. mm.	Elongation per cent	800 per cent Modulus kg/sq. mm.	T. S. kg/sq. mm.	Elongation per cent
R.R.I. in Hot Air	0.45	1.42	923	0.81	1.46	914
R.R.I. in Smoke	0.30	1.08	974	0.39	0.99	981
Estate A Smokehouse	0.56	1.52	989	0.86	1.46	905
„ B „	0.54	1.53	909	0.83	1.61	928
„ C „	0.54	1.51	908	0.84	1.59	924
„ D „	0.41	1.30	929	0.45	1.31	998
„ E „	0.35	1.04	922	0.39	1.05	995
„ F „	0.58	1.55	891	1.21	1.31	828
„ G „	0.47	1.32	905	0.57	1.38	960
„ H „	0.39	1.34	945	0.55	1.42	972
„ I „	0.39	1.30	932	0.49	1.38	986
„ J „	0.38	1.41	917	0.49	1.35	988

General conclusions regarding controllable variation

From the results of experiments described above taken in conjunction with other work it is believed that the variation in present day methods of preparing sheet is not responsible for as much of the variability as is usually attributed to it. Nearly 20 years ago de Vries found that rubber prepared in an identical manner on different estates appeared to exhibit as wide a variation in vulcanising properties as that normally found in estate rubber, and his conclusion is particularly interesting:

> " The " composition of the latex " therefore may cause as great a variation in the rubber as the preparation if not a greater one; and in proportion as the preparation on estates becomes more and more standardised, variation in the latex will be of more and more importance as a cause of variability in the product, because they depend on the condition and treatment of the plantation, which cannot always be regulated at will."

Uncontrollable variation

Time and space do not permit a detailed discussion of the effect of uncontrollable influences but the results of an experiment now in progress in Malaya on the *effect of the tapping system* are of interest and fully support de Vries' statement. A field of normal, well-grown seedling trees at the Experiment Station of the Rubber Research Institute was used for the experiment, the trees being 6 years old when tapping commenced. The field was divided into six full tasks, with two tasks of each of the following tapping systems:— alternate-daily tapping on single half-cut spiral, continuous tapping; daily tapping on single half-cut spiral alternate-monthly tapping; " Sunderland " system, third-daily tapping on two half-cut spirals, six months' tapping, six months' resting. The tasks were so arranged that when one " Sunderland " task was in tapping the other was resting and similarly for the daily alternate-monthly tasks. The trees were opened up as in normal estate practice and from the commencement of tapping the latex has been made into smoked sheet using a rigidly controlled and standardised preparation procedure. As far as possible all steps have been taken to prevent variation owing to conditions of preparation. The experiment has been proceeding since September 1936 and the results of vulcanising samples in " Captax " and rubber sulphur mixes representative of all sheet prepared from each task every month are given in Table VII. The modulus figures for the 60 minute cure in the " Captax " formula only are given together with those for the 120 minute cure in the rubber-sulphur mix. Tasks 3 and 4 which are both on the alternate-daily system

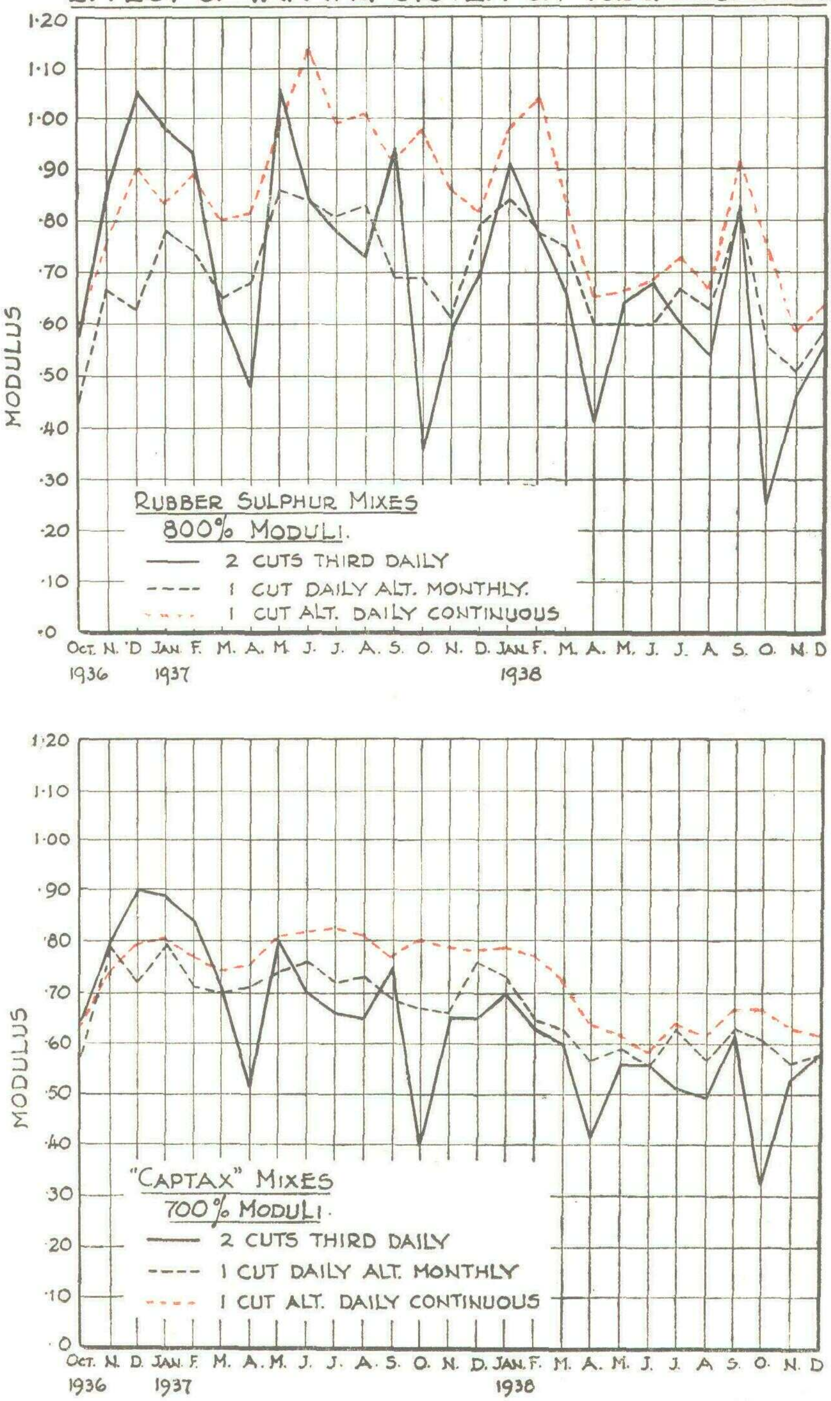
TABLE VII

Effect of Tapping System on Vulcanisation

MONTH		TASK 1 Two half-cuts spiral: Third-daily tapping: six months tapping six months rest MODULUS kg/sq.mm.		TASK 2 Two half-cuts spiral: Third-daily tapping: six months tapping six months rest MODULUS kg/sq.mm.		TASK 3 Single half-cut spiral alternate-daily continuous tapping MODULUS kg/sq.mm.		TASK 4 Single half-cut spiral alternate-daily continuous tapping MODULUS kg/sq.mm.		TASK 5 Single half-cut spiral daily tapping: One month tapping: One month resting MODULUS kg/sq.mm.		TASK 6 Single half-cut spiral daily tapping: One month tapping: One month resting MODULUS kg/sq.mm.	
		"Captax" 700 per cent	Rubber-sulphur 800 per cent	"Captax" 700 per cent	Rubber-sulphur 800 per cent	"Captax" 700 per cent	Rubber-sulphur 800 per cent	"Captax" 700 per cent	Rubber-sulphur 800 per cent	"Captax" 700 per cent	Rubber-sulphur 800 per cent	"Captax" 700 per cent	Rubber-sulphur 800 per cent
October	1936	0.64	0.58	—	—	0.66	0.64	0.59	0.51	—	—	0.57	0.45
November		0.80	0.87	—	—	0.76	0.81	0.72	0.70	0.79	0.67	—	—
December		0.90	1.05	—	—	0.75	0.79	0.84	1.02	—	—	0.72	0.63
January	1937	0.89	0.98	—	—	0.77	0.76	0.84	0.90	0.79	0.78	—	—
February		0.84	0.93	—	—	0.76	0.84	0.79	0.94	—	—	0.71	0.74
March		0.71	0.62	—	—	0.72	0.81	0.77	0.79	0.70	0.65	—	—
April		—	—	0.51	0.48	0.75	0.82	0.76	0.81	—	—	0.71	0.68
May		—	—	0.80	1.06	0.74	0.84	0.88	1.13	0.74	0.86	—	—
June		—	—	0.70	0.84	—	—	0.82	1.14	—	—	0.76	0.84
July		—	—	0.66	0.78	0.79	0.88	0.86	1.10	0.72	0.81	—	—
August		—	—	0.65	0.73	0.78	0.81	0.84	1.21	—	—	0.73	0.83
September		—	—	0.75	0.94	0.75	0.81	0.79	1.02	0.69	0.69	—	—
October		0.40	0.36	—	—	0.81	0.97	0.80	0.99	—	—	0.67	0.69
November		0.65	0.59	—	—	0.80	0.84	0.78	0.88	0.66	0.61	—	—
December		0.65	0.70	—	—	0.83	0.90	0.74	0.73	—	—	0.76	0.79
January	1938	0.70	0.91	—	—	0.78	0.92	0.80	1.05	0.73	0.84	—	—
February		0.63	0.78	—	—	0.82	1.07	0.73	1.01	—	—	0.65	0.78
March		0.60	0.66	—	—	0.77	0.86	0.69	0.81	0.63	0.75	—	—
April		—	—	0.41	0.41	0.67	0.67	0.61	0.64	—	—	0.57	0.60
May		—	—	0.56	0.64	0.62	0.62	0.62	0.71	0.59	0.60	—	—
June		—	—	0.56	0.68	0.58	0.67	0.59	0.70	—	—	0.56	0.60
July		—	—	0.51	0.60	0.66	0.73	0.62	0.73	0.63	0.67	—	—
August		—	—	0.49	0.54	0.64	0.67	0.59	0.67	—	—	0.57	0.63
September		—	—	0.62	0.83	0.71	0.97	0.63	0.87	0.63	0.82	—	—
October		0.32	0.25	—	—	0.67	0.77	0.67	0.75	—	—	0.61	0.56
November		0.53	0.46	—	—	0.64	0.57	0.63	0.60	0.56	0.51	—	—
December		0.58	0.56	—	—	0.64	0.68	0.60	0.59	—	—	0.58	0.59
		—	—	—	—	—	—	—	—	—	—	—	—

Fig. 2

EFFECT OF TAPPING SYSTEM ON VULCANISATION.



show appreciable differences in the first year of tapping after which the results are substantially the same. In Figure 2 in which the effect of the three systems is more readily seen, the mean modulus figures for tasks 3 and 4 are used.

The results of the tests in the rubber-sulphur are paralleled in the "Captax" mix and clearly indicate the Sunderland system of tapping to be the least desirable when judged by the effect on variability. There is a noticeable retardation in the rate of vulcanisation as the age of the trees increases and this is particularly evident in the Sunderland system. In each of the six-monthly periods of tapping in Task 1 the modulus rises to a maximum and then falls before resting begins, Task 2 behaves similarly except that in both periods of tapping April—September 1937 and 1938 there is a pronounced rise in September just before tapping ceases. Whether this is a seasonal variation or a peculiarity of the plot is not yet known although no indications of seasonal variation are apparent in the results of the other systems. This experiment will continue over a long period and in due course will provide valuable information on the effect on variability of the age of trees, height of tapping cut, change in tapping and other allied factors.

In concluding this paper it is hoped that the results given and views put forward will have indicated that the effect of variation in vulcanising properties is well recognised by the producers and that they are not apathetic towards the consumers' requirements. Variability however is a problem which does not appear to have an immediate solution because it seems to be caused, for the most part, by inherent variations in the latex, these variations being the result of differences in the trees themselves, in the soil and other environmental conditions under which they are growing, or in the methods used on the estate. Such differences are either entirely outside human control, or are a necessary consequence of economic conditions. The conclusion expressed by Sackett (1934) that the consumer must bear the burden of eliminating most of the variation by blending is unfortunately still a true statement of the present position.

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