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Consumer Appraisals of Natural Rubber

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Since synthetic rubber was introduced into commercial practice, the producers have inaugurated a number of changes that have improved the utility of synthetics to the consumer. These changes include desirable packaging features, cleanliness, control of viscosity and technical specifications.

A comparison of synthetic and natural rubber from a consumer standpoint demonstrates the advantages of these innovations. In appraising these characteristics, recognition is also made of the newer types of comminuted rubber, the constant viscosity (CV) feature, the similarity to the synthetic rubber presentation, and their impact on the consumer. The advantages of these rubbers are described in the light of current commercial practice. An important aspect of these considerations for CV rubber is the elimination of the degradation caused by plastication heat history. Laboratory and commercial practice experiments document the extent of the plastication deterioration which is manifested in higher heat generation.

Further test data are presented to compare end-product performance of conventional ribbed smoked sheets and the newer crumb rubber types with a clear superiority for the new techniques of rubber production.

The consumers' view-point for several areas of potential improvements in natural rubber are noted.

The communications existing between the producer and consumer of natural rubber are limited because of the great distances separating them. The Malayan Rubber Fund Board has responded to this problem and, through its subordinate organisations and Technical Service Advisory Groups, has made substantial improvements in this area. This discussion is intended to bring out some view-points of the consumer that may be provocative, and perhaps even refreshing, in strengthening the relationship between producer and consumer.

The merits of individual grades of rubbers have been reported by HEAL (1963), MORRIS AND NIELSEN (1961) and others; so, further discussion along these lines would be redundant. Moreover, the selection of individual grades of rubber depends upon market fluctuations and, in most cases, reflect a policy function of the particular consumer and the product involved.

Of late, considerable information has been reported by the Rubber Research Institute of Malaya as well as the various producers regarding the newer types of natural rubber and the improved methods of presentation. Considerably less information has been reported regarding the acceptance of these innovations in natural rubber by the consumer.

This report will concern itself with this acceptance based on how these changes influence the economics and quality of the end-product.

ECONOMIC COMPARISONS OF NATURAL AND SYNTHETIC

It should be recognised quite frankly that economics may influence a selection of natural rubber or synthetic. But it should be emphasised that such selection is based not on market price alone but on the total cost to the consumer on equivalent practical processing terms or marketable end-use properties.

Admittedly the synthetic rubber people have made significant advances which have enhanced the image of their product in the eyes of the consumer. They have worked closely with the consumer to present their product in the optimum bale size, the most convenient package with controlled specifications and comparatively narrow viscosity limits, and in these respects

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they have been fully cognizant of the total cost picture to the consumer.

This point can be clarified by tracing natural and synthetic rubber through normal factory handling procedures. To begin, *Figure 1* illustrates how natural rubber is received by the consumer. Either railroad box cars or trucks are unloaded with fork lift trucks. Because of the distorted, unwieldy shape of the natural rubber bales, it requires six to seven hours to unload a conventional railroad box car. The same weight of synthetic rubber can be handled in 45 minutes *(Figure 2)*, because the pallets are designed to move the maximum amount of material with the greatest efficiency. And this advantage in handling persists through all subsequent internal transportation.

The difference in processing natural and synthetic rubber from the receiving room to the Banbury mixer may be illustrated in a flow diagram.

In *Figure 3*, it may be noted that synthetic rubber can be moved from the receiving room directly to the Banbury mixer without any intervening steps. However, a number of additional steps is required in the case of natural rubber.

(a) Because natural rubber arrives 'bare back', the bale surfaces must be cleaned of all extraneous dirt and foreign material which they have picked up en route from the producers.

(b) The tendency for natural rubber to crystallise at low ambient temperatures requires several days' conditioning in a hot room at elevated temperatures prior to plastication.

Figure 1. Natural rubber as received.

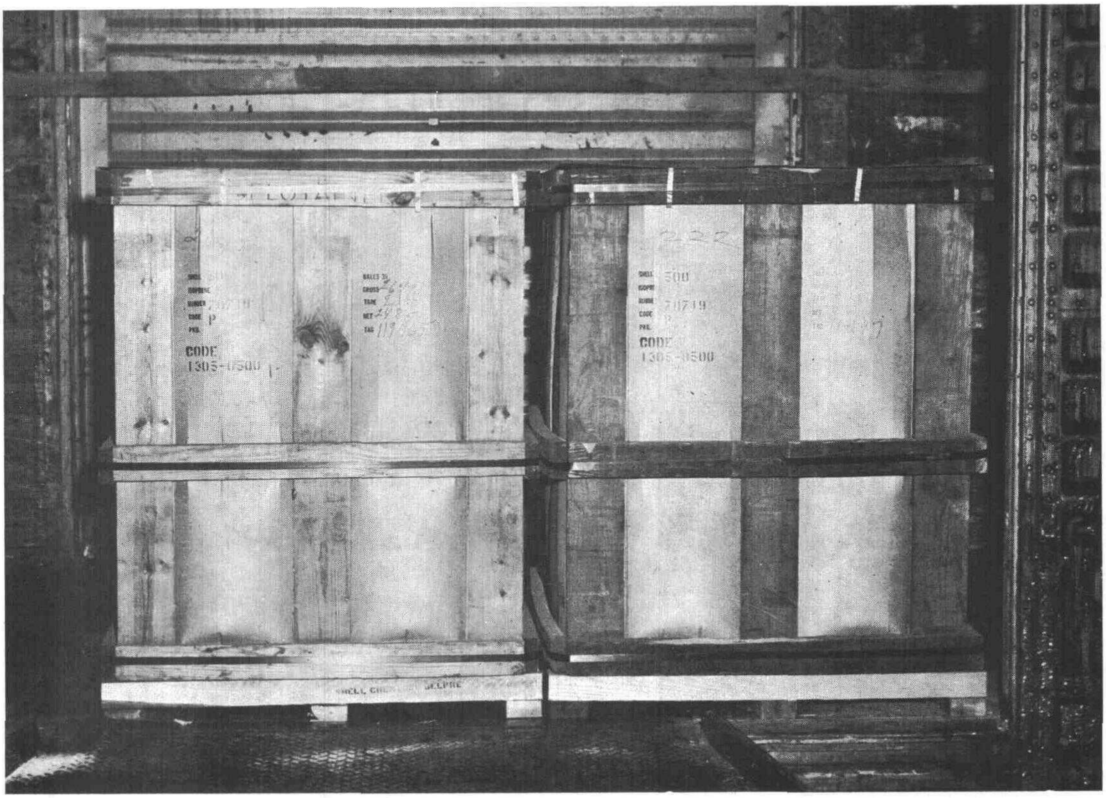

Figure 2. Synthetic rubber as received in pallets.

(c) The large natural rubber bales must be cut into smaller pieces for efficient handling.

(d) The Mooney viscosity of the material must be reduced by multiple passes through a plasticator or Banbury for optimum processability before delivery to the Banbury for mixing.

Thus, for comparable manufacturing purposes, natural rubber requires more processing steps, more factory area and more inventory stations all of which are additive to the cost of the material and affect the economics of its use. However, this comparison is incomplete unless it includes the newer types of crumb rubber which are currently presented in forms comparable to synthetics. And if the constant viscosity (CV) type is included, the rubber flow becomes similar to the synthetic pattern with only the hot room treatment differing from synthetic handling.

But this is predicated on the assumption that the packages arrive from the producer in an acceptable form and in an acceptable condition. And this is not always true. Let me illustrate this point in a somewhat dramatic fashion. *Figure 4* is a picture of a shipment of rubber in half-ton pallets as it arrived at one of our largest tyre plants. It is obvious that the pallets were demolished in transit and, while this is *not* typical, it is easy to understand that this shipment did nothing to help the cause of natural rubber. However, in direct contrast, it is interesting to note recent developments in shipments of rubbers *(Figure 5)* that were delivered from the producers' shipment point to the consumer in 20-foot long metal containers which hold approximately 17 tons each.

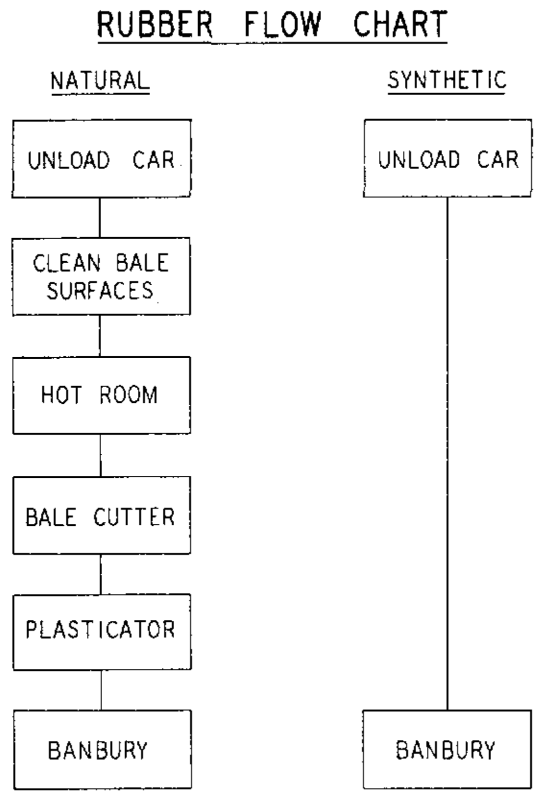

Figure 3. Natural and synthetic processing steps.

This method of shipment prevents damage during transit and, as can be seen in *Figures 5* and *6*, the pallets were in excellent condition upon arrival at the consumer plant and were easily removed from the container. The pallets were easily disassembled *(Figure 7)* and were quickly available for mixing operations. This modern method of shipment is currently being used by the synthetic industry for overseas shipment because of its economies, its handling efficiencies and the excellent condition of the pallets upon arrival. These advantages are so striking that it is almost inevitable that in time this will be the standard method for transporting natural rubber to the consumer.

But let us consider now some in-plant practices.

EFFECT OF PLASTICATION UPON QUALITY

Plastication is the most important item of consideration since it results in an additional cost as well as a loss in quality. This is particularly true when the plasticator is operating at high temperatures; then an oxidative-scission reaction takes place by exposing fresh surfaces for the absorption of oxygen (MULLINS AND WATSON, 1959). The effect of this reaction has been demonstrated on a typical tyre carcass stock using natural rubbers which were subjected to breakdown at various temperatures. The stocks were evaluated on a St. Joe Flexometer and the data in *Figure 8* show that running temperatures rise progressively with increasing plastication temperatures. Thus, a reduction of processing temperatures improves the product performance from a heat generation standpoint. It follows then that the complete elimination of plastication with its attendant heat history contributes to improved tyre performance. The heat history developed in rubber breakdown practice can be illustrated in *Table 1.*

In some factories where plasticators are not available, the rubber breakdown is accomplished in a Banbury mixer. A comparison of the two methods has been made on a commercial scale and the data are summarised in *Table 1.* Temperatures of extruded plasticated rubber normally range from 300°–350°F but the nature of the rubber and the plasticator procedure frequently cause temperatures to rise substantially higher. Banbury temperatures can be controlled more precisely but the rubber is

TABLE 1. RUBBER BREAKDOWN

Pass No.	Plasticator		Banbury	
	°F	Mooney	°F	Mooney
Original		95		95
1	310	78	305	81
2	340	61	305	70
3	260	56	305	62

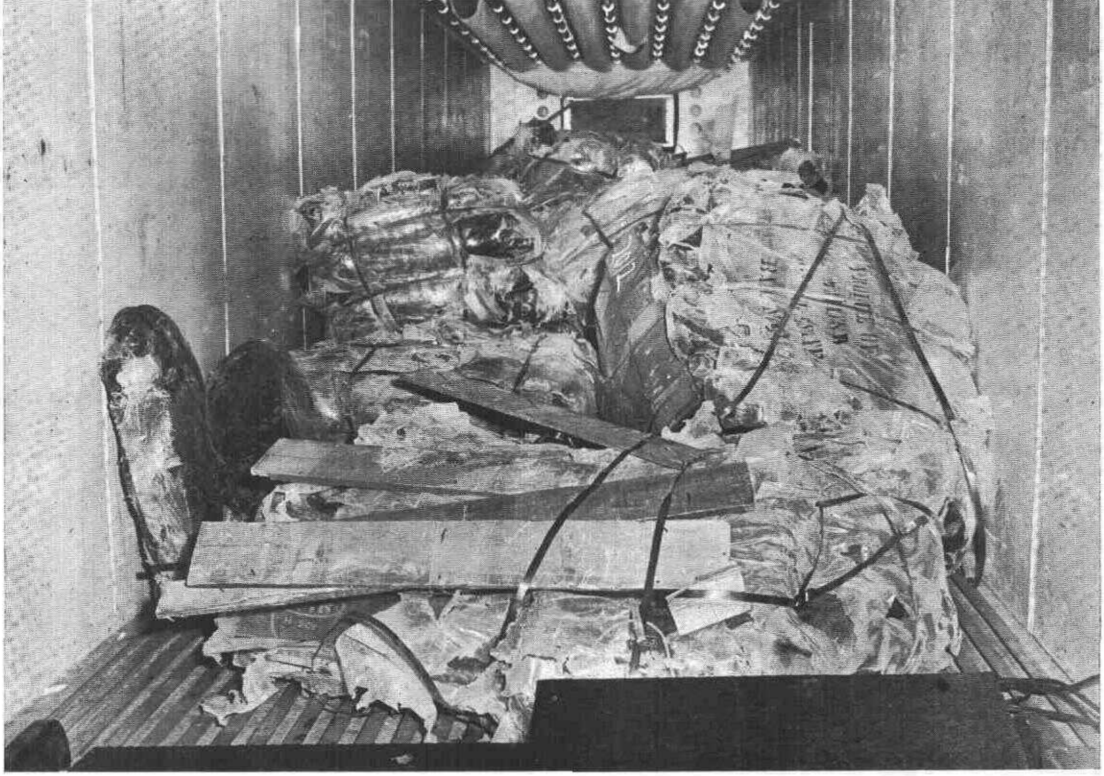

Figure 4. Palletised rubber demolished in transit.

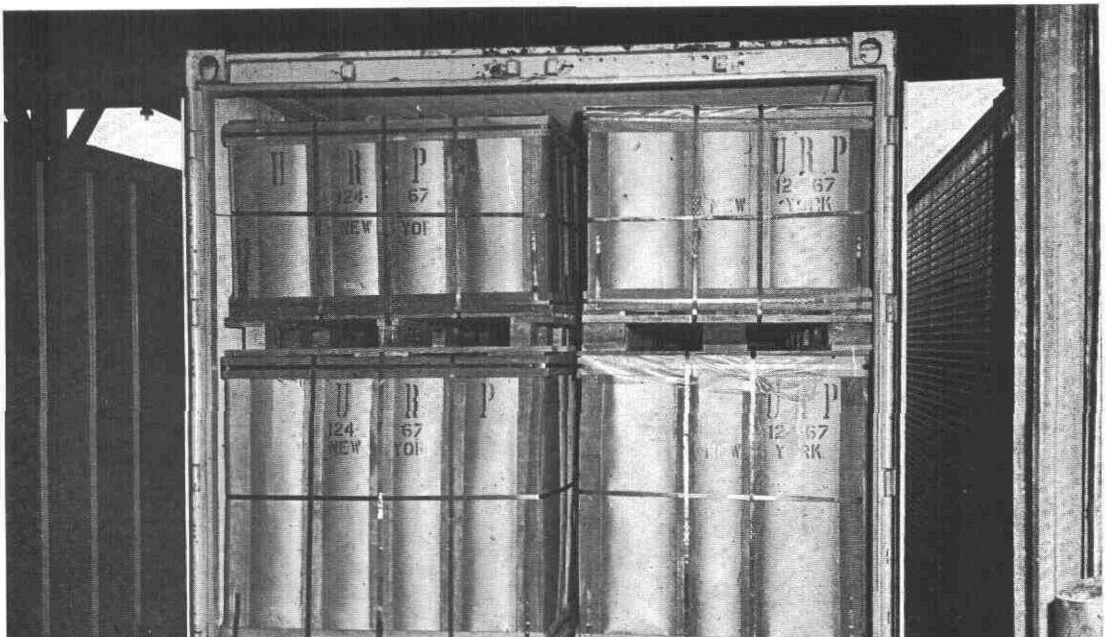

Figure 5. Containerised shipment of palletised rubber.

Figure 6. Removal of palletised rubber from container.

normally discharged from a breakdown cycle at approximately 300°F. Where multiple passes are required to reach the desired Mooney viscosity values, the exposure to heat history and oxidation are multiplied as well.

TABLE 2. BANBURY BREAKDOWN vs. GOODRICH HEAT BUILD-UP

Number of breakdowns	Mooney viscosity	Goodrich final temperature 60′,°F
0	97	226
1	70	232
2	59	242
4	47	249

A laboratory experiment was conducted to develop the relationship between successive Banbury breakdowns and ultimate heat development. The data in *Table 2* demonstrate this relationship on the Goodrich Flexometer and indicate progressively higher heat build-up in stocks with rubber subjected to increased rubber breakdown.

CONSTANT VISCOSITY ADVANTAGES

Thus, it can be developed that crumb rubber of the CV type offers the consumer distinct advantages in quality uniformity since it is offered at a specific Mooney level (65±5) which eliminates the jeopardy of the heat history exposure associated with conventional rubber breakdown procedures.

The development of the CV type of rubber is

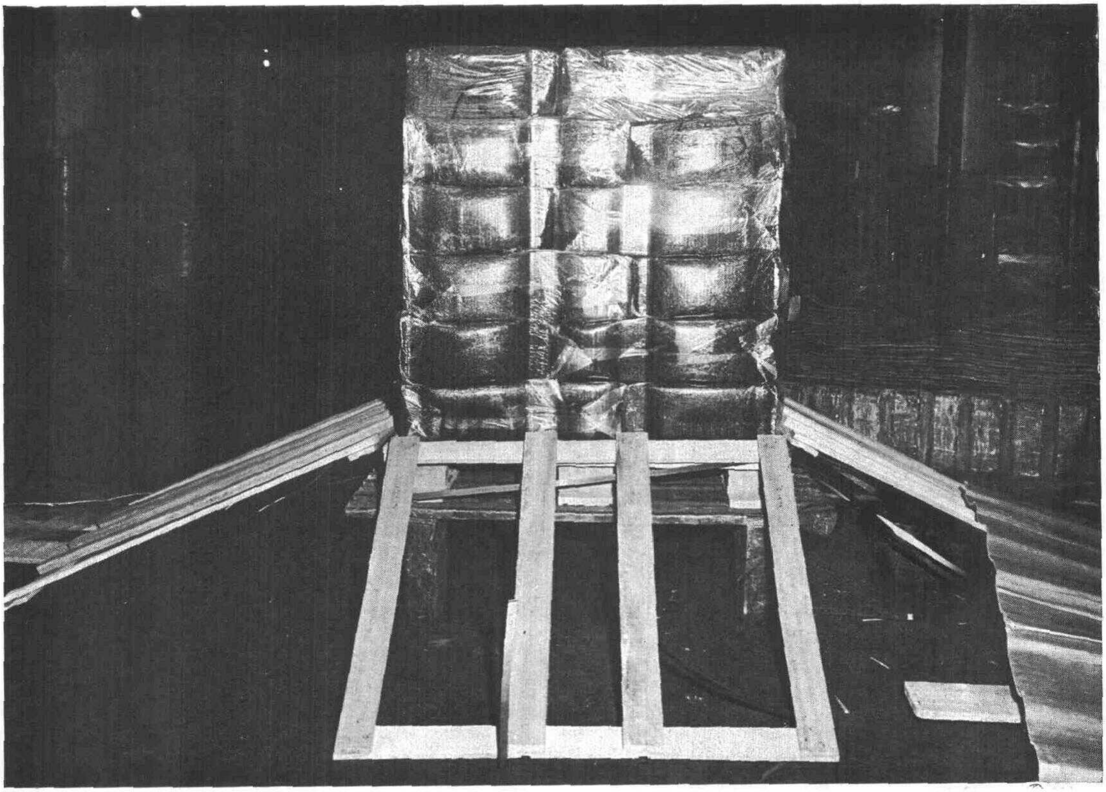

Figure 7. Disassembly of pallets.

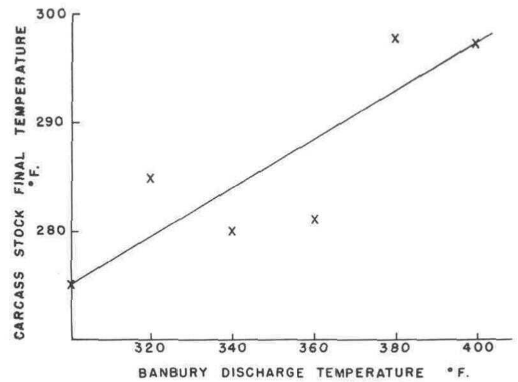

Figure 8. Degradation effect of rubber breakdown.

particularly timely because it comes at a time when obsolete plasticators are becoming less and less efficient because of mechanical deterioration. In many cases, their functions have been replaced by Banbury breakdown procedures but at a sacrifice in plant mixing capacity. CV rubber thus has the potential for increasing productive capacity by releasing rubber breakdown time for mixing operations. In forward planning for new factory installations, this is a well defined potential and capital expenditures allocated for rubber breakdown can be eliminated by planning for CV rubber adoptions.

FLEX-CRACKING RESISTANCE

Further evaluations have been made in all rubber tyre tread compounds comparing RSS1 vs. Heveacrumb SMR 5L rubber to determine groove-cracking resistance. With other properties comparable, laboratory data expressed in kilocycles at 150°C to failure on a De Mattia flex-cracking machine established a consistent superiority for the newer type of rubber over RSS1. Four separate evaluations are recorded in *Table 3*. The data indicate that SMR 5L exhibits an average improvement of 74% in flex resistance over RSS1, undoubtedly a manifestation of the lower dirt content.

ADHESION

Some apprehensions have been expressed regarding the possible jeopardy to adhesion caused by the castor oil in Heveacrumb to promote crumbling. Since adhesion is a matter of paramount importance in tyre manufacture, laboratory tests were conducted to determine the influence of castor oil on this property *(Table 4)*. Varying amounts of castor oil were mixed into a conventional, all-natural rubber tyre carcass compound and values obtained for dynamic cord adhesion, H adhesion and static strip adhesion.

These data do not indicate any depreciation in cured adhesion values with as high as 5 parts castor oil in the compound. To confirm these data, static strip adhesion tests were made on production Banbury mixed stocks featuring RSS and SMR 5L rubbers respectively. The data in *Table 5* represent adhesion values at a normal cure and a high temperature cure and indicate a slight bias in favour of the SMR 5L stock. It would appear, therefore, that the 0.7 part castor oil normally used in processing Heveacrumb will not ultimately affect adhesive properties. Moreover, extensive factory production use of Heveacrumb has disclosed no problems relating to raw tack.

TABLE 3. FLEX-CRACKING RESISTANCE

Tread	Kilocycles to failure at 150°C	
	RSS 1	SMR 5L
A	4500	9200
B	5300	6000
C	3570	7300
D	1760	3100

TABLE 4. ADHESION OF COMPOUNDS WITH CASTOR OIL

Adhesion test	Parts castor oil				
	0	0.5	1.0	3.0	5.0
Dynamic cord adhesion, min	>120	>120	>120	>120	>120
H adhesion at 250°F, lb	23	23	22	22	23
Static strip adhesion at 250°F, lb	17	16	22	23	25

SCORCH RESISTANCE OF CRUMB RUBBER

To those who are closest to the processing of rubber compounds, no item is of greater concern than scorch resistance for this characteristic may be responsible for production failures, increased scrap, poor fabrication, additional costs and a host of problems to torment factory production personnel. It is quite natural, therefore, for plants to evaluate this property from a defensive standpoint and to do it quite independently and document it in careful detail for any change made. The introduction of Heveacrumb in substantial quantities prompted such independent investigations in two plants by their respective personnel under production conditions over an extended period of time *(Table 6)*. The data were accumulated on stocks with different rubbers but comparable physical properties and curing rates.

TABLE 5. STATIC STRIP ADHESION —ALL NR CARCASS STOCK

Cure	RSS (lb)	SMR 5L (lb)
45 min at 293°F	14	17
11 min at 325°F	13	17

TABLE 6. SCORCH IMPROVEMENT WITH HEVEACRUMB

Stock	Average scorch values, minutes at 275°F			% Gain
	RSS	SMR 5L	SMR 5CV	
176	7.3	–	8.4	15.1
1766	8.4	–	10.0	19.1
4366	7.8	9.1	–	16.7
14005	14.0	15.8	–	12.8
14026	13.7	–	15.7	14.6
12832	18.0	–	21.0	16.7
2866	7.5	–	10.0	33.3

The data demonstrate a consistent improvement in scorch resistance for Heveacrumb in a number of stocks in two separate plants. Monsanto Rheometer data have confirmed these observations by demonstrating a longer induction period. This advantage has been utilised to improve processing for several stocks which were on the borderline for adequate scorch resistance.

PRODUCTION EXPERIENCE WITH CRUMB RUBBER

It may be interesting to appraise new process rubber from the factory production standpoint by reviewing some production management records.

TABLE 7. EFFECT OF CRUMB RUBBER ON MILLROOM SCRAP

Time period, months	Heveacrumb, %	Millroom scrap, %
24	0	7.00
12	9.82	6.24
6	15.54	5.22

In one of the footwear plants, Heveacrumb was used to replace conventional natural rubber in one of their applications. The advantages of this substitution were clear to the observers of this particular production operation but it was interesting to note that this specific change made sufficient impact on the total millroom operation to reflect a significant reduction in total defective material *(Table 7)*.

The data established a reference point of 7.00 % of the total millroom output as defective for a number of reasons. The millroom produced compounds of natural rubber, synthetic and blends of natural and synthetic. Heveacrumb CV rubber was introduced at a level of 9.82% of the total polymer and over a twelve-month period the per cent defectives for the total millroom dropped to 6.24%. During the following six-month period, Heveacrumb CV was used at a 15.54% level of the total polymer usage and the impact on the total production was sufficient to drop the total millroom defective material to 5.22%.

Undoubtedly, much of the reduction was due to the lower dirt content which has a profound effect on processing, particularly at low gauges or 'feather edges'. In some cases, an extra straining operation was eliminated which was previously necessary because of the high dirt content on bale surfaces.

Since these data were gathered over an extended period of time under actual production conditions with no other important changes made, the improvements were considered by that management to be substantial and significant.

LOW MOONEY IN TYRE PERFORMANCE

While the viscosity of rubber is generally held to certain prescribed limits for optimum processability, it can also have an influence on the ultimate serviceability of the vulcanisate. One of the critical requirements of off-the-road tyres is the resistance to tread cutting, chipping and flaking caused by rough, irregular road surfaces that such tyres must encounter in service. In an evaluation of the effect of viscosity on tread chipping, a group of tyres with two levels of Mooney was produced and placed in service in a strip mining operation. The picture

(Figure 9) shows a representative section of a tyre in which the left half of the tread used rubber broken down to a Mooney of 56 while the right half used rubber broken down to a Mooney of 74 prior to mixing. In all other respects, these two compounds were identical. This clearly demonstrates that lower viscosity tread stocks have greater resistance to off-the-road deterioration in service.

It is our belief that the increase in Mooney viscosity that takes place from production to consumption imposes internal strains in the matrix that can persist through processing and curing and are responsible for lower chipping resistance in service.

This can be improved in two ways, *viz.*, increased rubber breakdown to break up the internal strains or by eliminating the viscosity increase after production, *i.e.*, the constant viscosity (CV) method. Investigations are currently being carried out to test the validity of these premises.

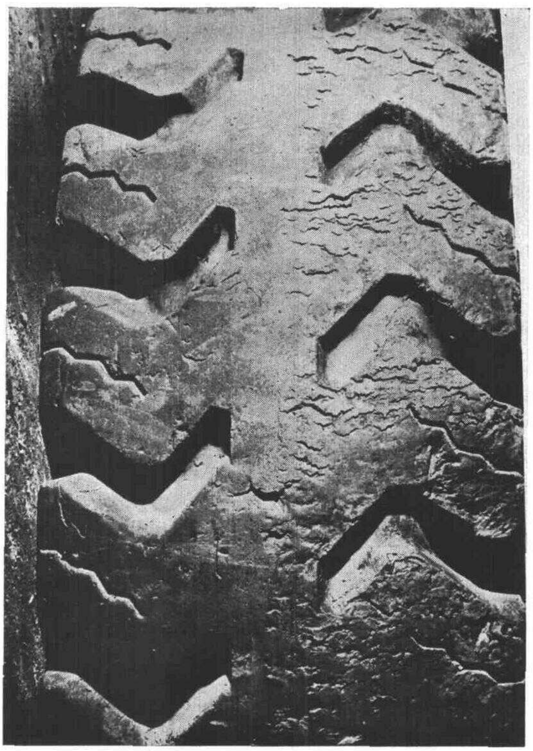

Figure 9. Effect of Mooney viscosity on chipping resistance of tread compounds.

APPRAISAL FOR THE FUTURE OF NATURAL RUBBER

Thus far we have discussed recent natural rubber developments and their impact on the consumer. This appraisal would be less than candid unless we also recognised some of the deficiencies of natural rubber and the opportunities for improvement to match or surpass the moving target of synthetics. With that preamble, we propose a few suggestions as follows:

(1) As stated earlier, the susceptibility of natural rubber to crystallisation at low ambient temperatures requires operations that are not necessary for synthetics. This requirement can be demonstrated in *Figure 10*, which is a picture of a Banbury mixed piece of stock containing a blend of natural rubber and two synthetics. The natural rubber had been shipped during the winter season and upon arrival was stored in the factory at room temperature prior to mixing. Inadvertently, the hot room treatment had been omitted. The picture shows dark areas which are undispersed crystallised natural rubber. The two synthetic polymers behaved normally, blended easily and incorporated the pigments without difficulty. Obviously this problem is solved by subjecting the rubber to elevated temperatures for a period of days. However, it is a problem which is practically related to natural rubber alone and thus places it at a disadvantage in comparison with synthetics. A practical method for introducing a modest degree of isomerisation into the rubber may very well minimise this problem but this should be optimised with the loss in raw tack strength which occurs with reduced polymer crystallisation.

(2) The ever increasing demands of an expanding economy are putting greater pressures upon higher productivity. In rubber manufacturing, these pressures are expressed in shorter curing cycles at

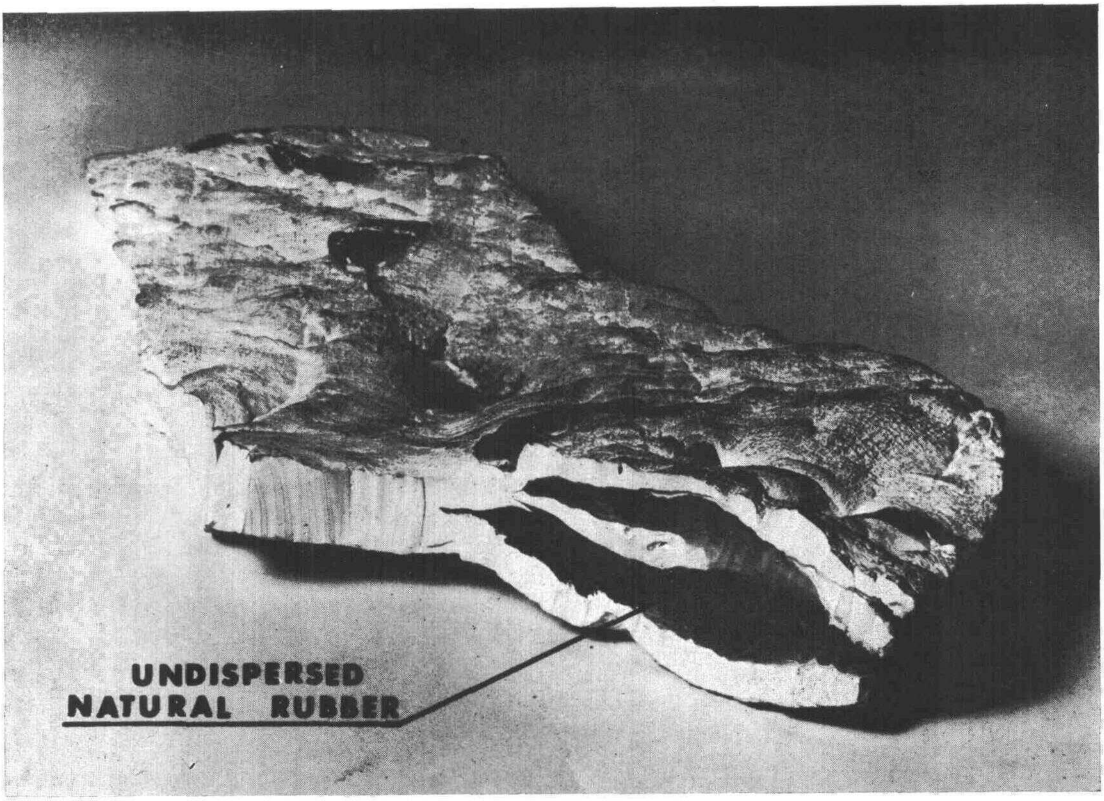

Figure 10. Undispersed crystallised natural rubber.

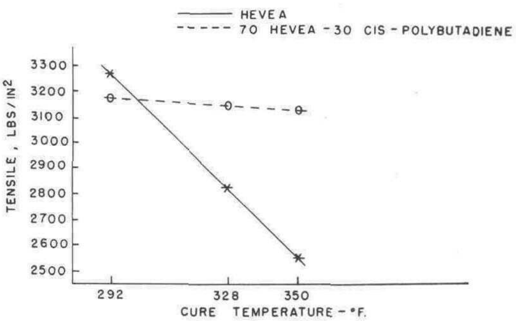

Figure 11. Tensile loss at higher cure temperatures.

higher temperatures. Such changes are made at some sacrifice in physical properties and service performance, for *Hevea* rubber is highly sensitive to higher vulcanising temperatures (SMITH, 1961). This can be demonstrated in *Figure 11* which shows a greater decline in tensile strength with natural rubber than with a blend of natural and synthetic (*cis*-polybutadiene) with increasing temperatures of cure (MCCALL AND DEDECKER, 1964). Low heat generation properties *(Figure 12)*, so important in tyres, also suffer at higher temperatures of cure and, in overcures, the disparity between natural and synthetic is greater and is in favour of synthetics.

(3) Carbon black masterbatching is not new for natural rubber and has been

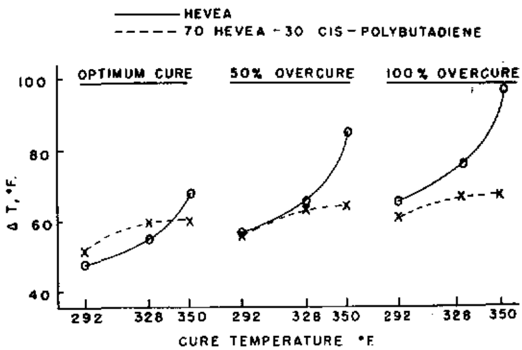

Figure 12. Heat generation at higher cure temperatures.

covered in the literature recently by SHIPLEY (1967). However, several new technological advancements have been made to improve dispersion in natural rubber latex and at least one carbon black producer is considering the erection of a carbon black plant for this purpose in Southeast Asia. This development opens up an entirely new approach and new potentials for carbon black masterbatching of natural rubber.

(4) Many consumers use blends of natural rubber and synthetics and it has been suggested previously that such blends could be improved (GEE, 1961). There is currently some belief that blends have produced synergistic quality improvements (MCCALL AND DEDECKER, 1964). This has inspired several research groups to pursue new methods of blending polymers more intimately to promote still further quality improvements. This technology may disclose entirely new areas of commercial possibilities for the producer as well as the consumer.

(5) A relationship has been established between processability and the molecular weight distribution of synthetic rubber. This has provoked a more comprehensive study of this factor which has been implemented by improved instrumentation now available commercially. The study of molecular weight distribution for natural rubber may reveal some profitable new technological areas.

(6) In other areas, natural rubber is not presented in as many forms as synthetics. One example is oil extension which has been explored for natural rubber and discussed extensively by GROSCH AND SWIFT (1966). The economies this process represents, particularly when the oil is added *in situ*, cannot be ignored. The recent developments in improved palleting and shipping would aid in the presentation of this product.

These are areas that appear to represent great opportunities for technological advancement. Aside from those mentioned, it is not too difficult to visualise other dramatic accomplishments in polymers. Solution masterbatches involving phase transfer systems to improve carbon black dispersion are in an advanced stage of development. True, these are all innovations that depart from the traditional concept of natural rubber production, but it must be admitted by even the most conservative elements that the activity in synthetics make these realistic goals to enhance the position of natural rubber.

CONCLUSIONS

In summary, it may be said that large-scale uses of crumb rubber in a number of production factories have established significant advantages to the consumer. The low dirt content has permitted better processing, lower scrap and improved quality. In practice, a significant upward trend in scorch resistance has been noted. Perhaps the outstanding technological development is the constant viscosity rubber which eliminates much of the mastication required and its attendant degradation of physical properties.

These advancements have been sustained by modern packaging and shipping conditions which are readily recognised by the consumer. Other improvements, based on consumer requirements, have been suggested that may be developed through further research to enhance the position of natural rubber.

Finally, in retrospect, the technical improvements of the last few years have made a dynamic thrust forward. The potentials that appear on the research horizon bid for an exciting and promising future for natural rubber. With all of these advantages there is no reason why natural rubber cannot at least hold its own. With judicious recognition of consumer economics it can even penetrate the market of synthetics.

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DISCUSSION

Chairman: Mr. M. Alcan

In reply to Mr. R.N. Muthurajah, who enquired why more of the classical forms of natural rubber such as sheet was not shipped as Standard Malaysian Rubber or in similar forms of packaging, Mr. Bekema said there was a lack of communication between producers and consumers concerning what was required. His company, Uniroyal Inc., USA, had therefore, undertaken a special investigation in order to improve such liaison. Concerning Mr. Muthurajah's further enquiry, a survey of all Uniroyal plants showed a wide range in the actual savings in cents per pound by using crumb rubber instead of the conventional forms. Therefore, Mr. Bekema was reluctant to give a figure representative of all plants, companies or countries, because it depended on the particular items produced and other economic factors.

Such advantages of crumb rubber as containerised packing, carbon black masterbatches and oil extension were well known to producers, according to Mr. A.H. Ritchie, who enquired if they were appreciated in the United States, the main synthetic rubber producing country where masterbatches were penalised by an extra import duty; moreover, the Shipping Conference freight rates were higher for containerisation. Mr. Bekema said he was aware of these tariffs, but he hoped that they would be removed eventually; approaches were now being made in Washington.

Tariff restrictions had limited the evaluation of SMR LV in the United States to exploratory tests only; therefore adequate comparison with CV was not possible. Mr. P. van Gelder also enquired if, compared with RSS 1, there was a disadvantageous lengthened cure time, such as was usually associated with the improved scorch resistance, because the latter was claimed for SMR 5L and CV. Mr. Bekema confirmed that the comparison had been made at equivalent curing rates and the improved scorch resistance was real as shown by longer induction periods in the rheometer test.

In reply to Mr. Sathappan, he said that no blooming of castor oil on Heveacrumb rubber had been noticed at Uniroyal.

Mr. C.W. Thompson hoped that the authorities concerned would take due note of the importance of containerisation as stressed by Mr. Bekema and allow container transport on the roads and facilitate the handling of containers at the ports. This would benefit producers and consumers; Guthrie and other companies were anxious to be able to implement progress in this field.