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CHALLENGES FACING NATURAL RUBBER AT THE BEGINNING OF THE SECOND HUNDRED YEARS

LEONARD MULLINS
(*Malaysian Rubber Producers' Research Association, Hertford, England*)

INTRODUCTION

Necessity is said to be the mother of invention. There is no doubt that the transplanting of rubber from Brazil to the East exactly one hundred years ago — which we are celebrating at this Conference — was a result of a few men of vision who saw the need to provide increasing supplies of rubber and made plans. There is no doubt that the initial growth of the synthetic rubber producing industry resulted from the need to provide alternative sources of supply for rubber and that its subsequent rapid development resulted from the need to provide much greater quantities of rubber than the natural rubber producing industry could provide alone. There is no doubt that the development and adoption of new presentation and technical specification schemes resulted from the need to compete with synthetic rubber on equal terms. And looking to the future there is no doubt that the need for many of the developments which will occur in the next few decades is already perceived and it is to these that I wish to direct our attention today.

SUPPLY AND DEMAND

The first three figures, due to Ruebensaal, give information on the growth of natural and synthetic rubber consumption over the past hundred years. First, the steady and continuing growth of natural rubber consumption which reaches 3·7 million tons this year and is close to 34% of total rubber production (Fig. 1).

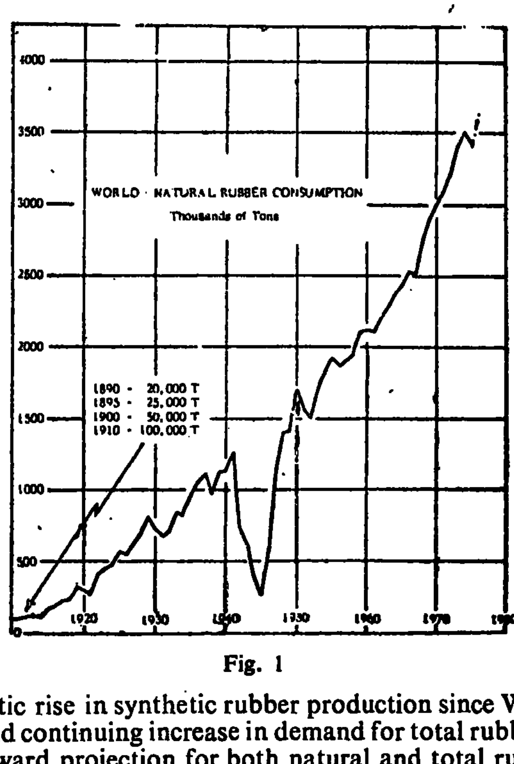

Fig. 1

Second, the dramatic rise in synthetic rubber production since World War II, which reflects the rapid and continuing increase in demand for total rubber (Fig. 2). Third, Fig. 3 shows a forward projection for both natural and total rubber consumption. It draws attention to a developing sophistication in the production of synthetic rubbers in which speciality synthetic rubbers will become increasingly available with properties specifically required for particular processes or applications. This is a feature which will be referred to later.

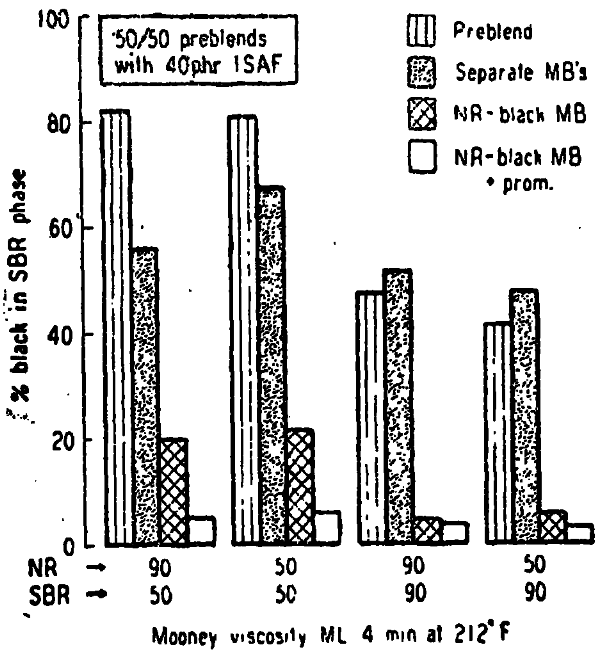

Fig. 2. Effect of method of blending on concentration of black in separate phases of NR/SBR blends

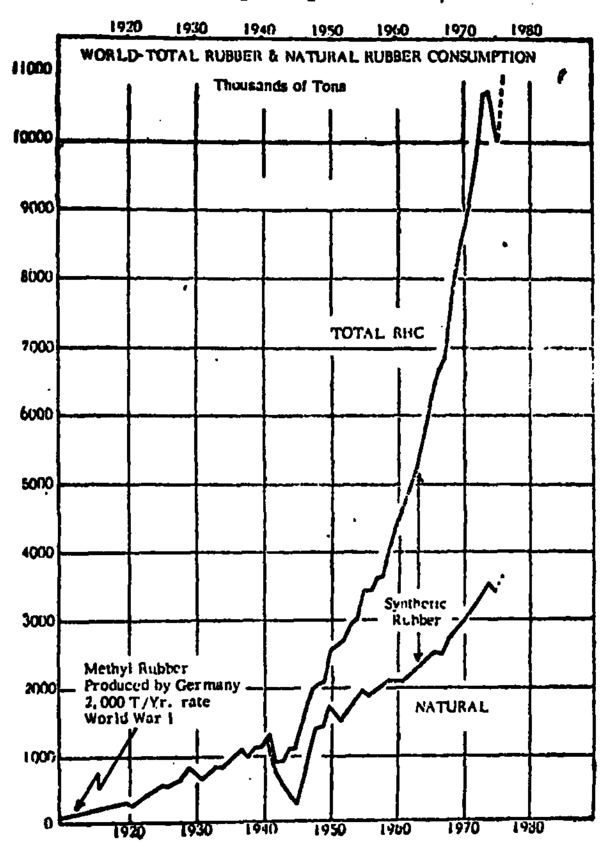

Fig. 3

The fact that natural rubber accounts for only 34% of the world rubber market provides no information whatsoever concerning future actual or potential demand because this figure is controlled by the current supply of natural rubber. Since the end of World War II the supply of natural rubber has never matched demand for rubber and the gap had to be filled by synthetic rubber.

If natural rubber is to retain its status in terms of market share then using Ruebensaal's projection 10 million tons of natural rubber must be produced yearly by the early 1990s. To increase its status to say 40% of the market will require 12 million tons a year.

To achieve this tonnage from existing acreages will require trebling the rate of production per acre. Such increases are feasible, if full use is made of yield stimulation, novel tapping methods, early maturation and other agronomic techniques as has been demonstrated in the address by Tan Sri, Dr. Sekhar.

This provides the first major challenge. If natural rubber does not achieve this supply rate then there will be a theoretical shortage of isoprenic type rubbers leaving a gap to be filled by synthetic polyisoprene or some other resilient synthetic rubber. More remotely, there is currently talk of the potential of an old favourite, the shrub *Guayule*, though it may be predicted on several counts that it cannot match the potential of *Hevea*.

PRICE

Price is certainly the first factor in the eyes of consumers and in this respect the prices paid for synthetic rubber have been much more stable over an long period than those paid for natural rubber. The second challenge is thus to ensure stable and sensible prices for natural rubber, in the same range as the going rate for the general purpose synthetic rubber SBR. Stability is the main requirement, violent fluctuations in the price of natural rubber militate against its acceptability to consumers and are a major element in encouraging switching from natural rubber to synthetic rubber in applications where the use of natural rubber is technically sensible, and of discouraging switching in the reverse direction when the price of natural rubber is favourable.

Moves to meet this challenge and to establish a degree of stability are already in train. The active discussions among the ANRPC countries have produced general agreement which include supply rationalization as well as operation of a buffer stock.

TECHNICAL PERFORMANCE

Although price is one of the main factors influencing choice, technical performance both during processing and in service is of greater importance. If a given rubber cannot achieve the required properties then it will not be used, no matter how cheap.

Processing

The main requirement of a customer who regularly buys a particular material is that its properties should not vary. This requirement applies with special consequence to the purchaser of raw rubber — the rubber product manufacturer — who has to masticate, mix, shape and vulcanize the raw material before selling his finished products. Uniformity of processing behaviour is essential not only for consistency of the finished products, but also for the smooth flow of material through the factory.

In the past when processing units were small then difficulties which occurred could be overcome at the expense of loss of production, but in larger units with more efficient, complex and expensive equipment, and with less manual and more automatic operations, processing difficulties such as variable mixing cycles, non-uniform extrusions, scorch and variable cure cannot be tolerated in the same way. Thus increasingly manufacturers are making more stringent demands for uniformity in viscosity, nerve, and vulcanization characteristics, while elimination of the need to thaw and to masticate natural rubber would provide an added bonus.

Thawing : Raw natural rubber if it is stored at low temperature crystallizes and becomes hard and board-like. Thus in cold climates the first operation with natural rubber is to thaw it either by supplying heat to the warehouse or by moving it to a hot room. The challenge is to produce natural rubber which does not crystallize or crystallizes more slowly at low temperatures. Factors which influence the ease with which natural rubber crystallizes are not well understood and different batches and grades may show wide differences in their rates of crystallization. Thus it seems likely that significant advantage could be obtained by closer control of some of the production variables. For example, it has been shown that the temperature of baling has a significant effect on the rate of crystallization (Fig. 4), and that if the rubber is baled at low temperatures it is more prone to crystallize and there appears to be an optimum range of baling temperatures.

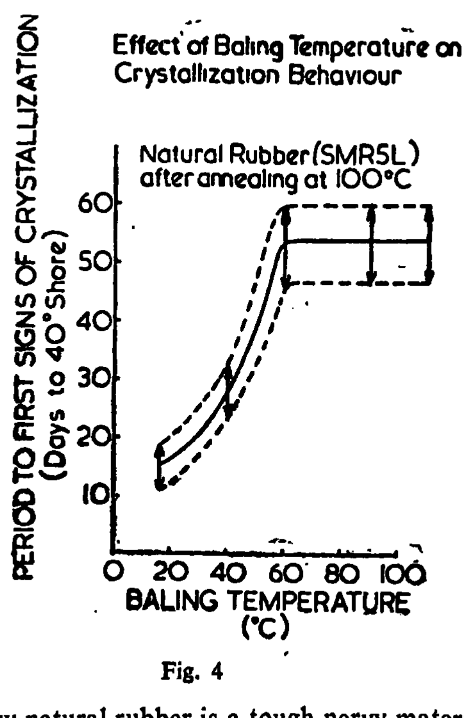

Fig. 4

Mastication : Raw natural rubber is a tough nervy material and it is normally necessary to masticate it to soften it before the various compounding ingredients can be added. Synthetic rubbers in general do not require mastication thus saving the manufacturer the cost of this process. The viscosity stabilized (CV) natural rubbers marketed under the SMR scheme and oil extended natural rubber emulate the synthetics and in most cases can be processed without mastication and thus provide possible solutions to this challenge.

Shaping : After mastication and mixing the rubber compound is shaped before vulcanization into the final product. At this stage the manufacturer requires that the compound should be uniform in its flow properties. Here the nerve of natural rubber which advantageously enhances its toughness provides a difficulty and variability of nerve and of thixotropic hardening which are more evident in natural than synthetic rubbers can lead to non-uniform extrusions (Fig. 5). The sources of these differences are not understood and practical solutions need to be found to satisfy the requirement of easier and faster processing.

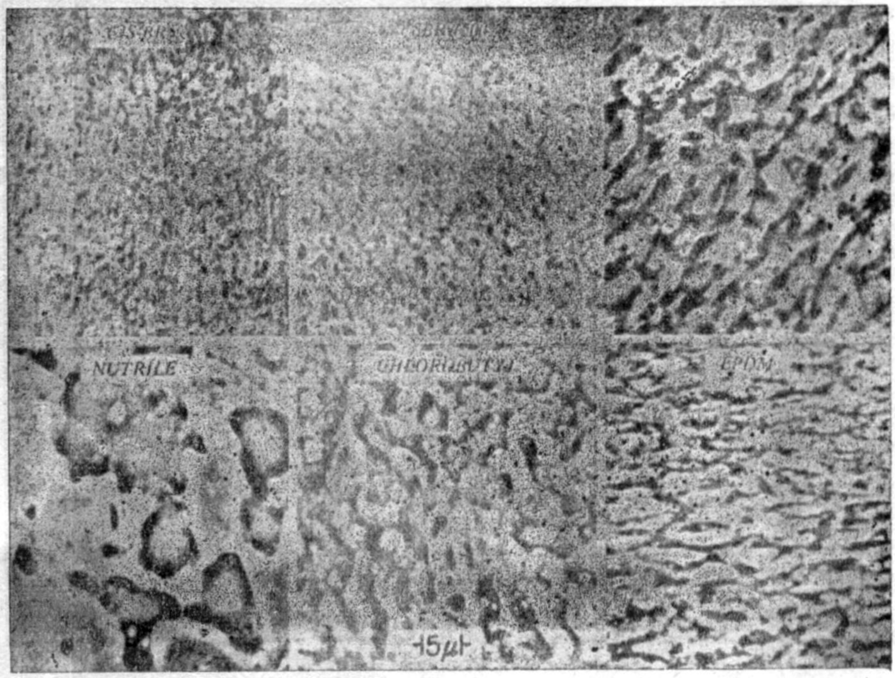

Fig. 5

Vulcanization : This is the final step in which the mouldable compounded rubber is turned into the finished product. Control of vulcanisation so as to get the required properties entails close control of time and temperature. In turn this depends on the raw rubber and the various ingredients which have gone to make up the mix. This is a critical matter, there is a temperature/time region within which the producproperties are optimal and outside this region they may be much inferior. Consequently a good deal of effort is spent on making sure that the conditions are just right, and for this uniformity in the vulcanization behaviour of the raw rubber it essential.

For control purposes it has usually been found adequate simply to measure the modulus under selected and specified vulcanization conditions and the ' MOD ' test in Technically Specified natural rubber was introduced to meet this need. However traditional stress-strain methods of determining vulcanization characteristics are being supplanted in the consumers' factories by a new type of test involving curemeters. These are being used in production quality control to detect unacceptable batch variation due to lack of consistency in the raw materials, incorrect compounding or inadequate mixing. Accordingly synthetic rubber producers are moving towards the use of curemeters for the release testing of general purpose rubbers. This trend will continue and we can anticipate increasing pressure to provide more precise information about the consistency of vulcanization behaviour of natural rubber.

An even more important challenge is to develop vulcanization systems for natural rubber which show improved resistance to reversion and ageing. In reversion crosslinks introduced during vulcanization are destroyed on further exposure to high temperature such as in over-vulcanization or in arduous service. This results in loss of modulus and other physical properties and, according to many consumers, is a major deficiency of natural rubber compared with its less susceptible synthetic rivals. Unfortunately the problem is particularly important in those very articles — heavy duty and giant tyres — which for overriding technical reasons constitute a major market for natural rubber. Marked improvements in resistance to reversion and ageing have resulted from the development " efficient vulcanization " (EV) systems which produce simpler more thermally stable sulphur crosslinks but lower the initial strength and dynamic properties. Probably the best compromise in sulphur vulcanizates is the semi EV system which uses intermediate accelerator-sulphur ratios, and is becoming increasingly popular in the rubber industry.

However, it has been necessary to break away from conventional sulphur vulcanization to achieve the best balance between physical properties and resistance to reversion and the new ' urethane ' vulcanization system provides vulcanizates with physical properties equal to or better than those of conventional sulphur vulcanizates but with freedom from reversion (Figs. 6 & 7). Urethane vulcanization should find application in heavy duty and giant tyres and in premium products such as engineering components.

Service performance

Whatever the price or ease of processing of a rubber the product into which it is made must satisfy the users' performance requirements. These vary widely from one product to another. Natural rubber comes from the tree with an excellent combination of physical properties for its role as a general purpose rubber. There is, however, a continuing consumer demand for improvements both general and specific related to areas such as vulcanization, ageing, and abrasion resistance, or for the upgrading of certain properties such as air permeability, solvent and flame resistance, or for the tailoring of hardness and damping characteristics to specific engineering application.

For many of these targets it will not be sufficient to rely on compounding improvements and either a more fundamental alteration of the natural rubber molecule by chemical modification or the use of rubbers in blends to make optimum use of the best properties of the different rubbers is required.

CHEMICAL MODIFICATION OF NATURAL RUBBER

A great deal of effort has already been expended to achieve useful chemical modifications of natural rubber. Thus, viable methods of cyclization, depolymerization, and isomerization of natural rubber are available. Also natural rubber has been chlorinated, hydrochlorinated, epoxidized and has had added to it many reagents including thiols, aldehydes, sulphur dioxide, maleic anhydride, maleimides and trichlorobromomethane. The grafting of polymers such as polystyrene and polymethylmethacrylate has been accomplished in a variety of ways. Commercially the methacrylate grafts have achieved the greatest importance. Processes for cyclization (used for moulding and reinforcing resin), depolymerization (used for castable mouldings and binders), isomerization (used for anti-crystallizing rubber), chlorination (used for paints) and hydrochlorination (used for packaging) have reached commercial scale but present markets are small.

Economic considerations are obviously of prime importance and it is necessary to consider the distinct targets of chemical modification. First, the attachment of chemically reactive pendant groups to provide sites for crosslinking, grafting, improved reinforcement, and for binding protecting groups of various kinds such as antioxidants and bactericides. For these purposes a modification level of 1 mole % would be adequate and assuming that the modifications can be carried out cheaply in latex or dry rubber processing the price of the rubber need not increase more than approximately 10%. Second, if physical properties such as hardness hysteresis *etc.* need to be improved then higher modification levels of 5 — 25 mole % will be required with a *pro rata* increase in cost. Even so, where the application is important enough and in the present economic climate where specialist synthetic rubbers have become more costly, such a premium may be quite acceptable.

The immediate challenges are quite clear. Can natural rubber's properties be upgraded in this way ? Can new materials be derived from natural rubber and take their place alongside plastics and synthetic rubbers ?

BLENDS WITH NATURAL RUBBER

This provides the topic for a separate lecture at this Conference and here I will restrict myself to saying that it appears that it will become increasingly unusual to find a rubber — natural or synthetic — which does not have its basic properties enhanced by blending or combining with another rubber or material.

By improving its performance in this way, natural rubber may : (1) retain markets in which there is a recognized need for improvement, (2) become competitive in applications for which it is not normally considered, and (3) be processed by quite new techniques.

As yet there is little understanding of the factors which control the dispersion during blending and of the consequences of changes in dispersion. But there is now promise that effort spent on blending generally to improve product performance will have important practical benefits to the natural rubber producing industry.

NEW FORMS OF NATURAL RUBBER

Rubbers, both natural and synthetic are difficult to process — heavy machinery is required to masticate, mix, shape and mould, and high shearing forces and much energy is involved in the addition of reinforcing fillers. Over the years it has become popular to talk of reform of these traditional methods of manufacturing articles from rubber and to contrast them unfavourably to those used by the plastics industry and to suggest that the ideal rubber should be capable of being handled as a fluid so that it could flow through highly automated and continuous factory processes. These ideas have already been partly translated into reality and the synthetic rubber producers have already developed and marketed such materials as powdered rubber (5,000 tons per year), liquid rubber (30,000 tons per year) and thermoplastic rubber which eliminates the vulcanization process (100,000 tons per year).

The trend is apparent although it is not yet clear whether these new forms will only be used in peripheral applications. But if the trend continues the time will come when many rubber product manufacturers, having found benefits to be derived from the use of such forms of synthetic rubber, will redesign their factories to make exclusive use of them and if by that time natural rubber is not available in similar forms its competitiveness *vis-a-vis* synthetic rubbers will be diminished with potentially serious consequences for the natural rubber producers.

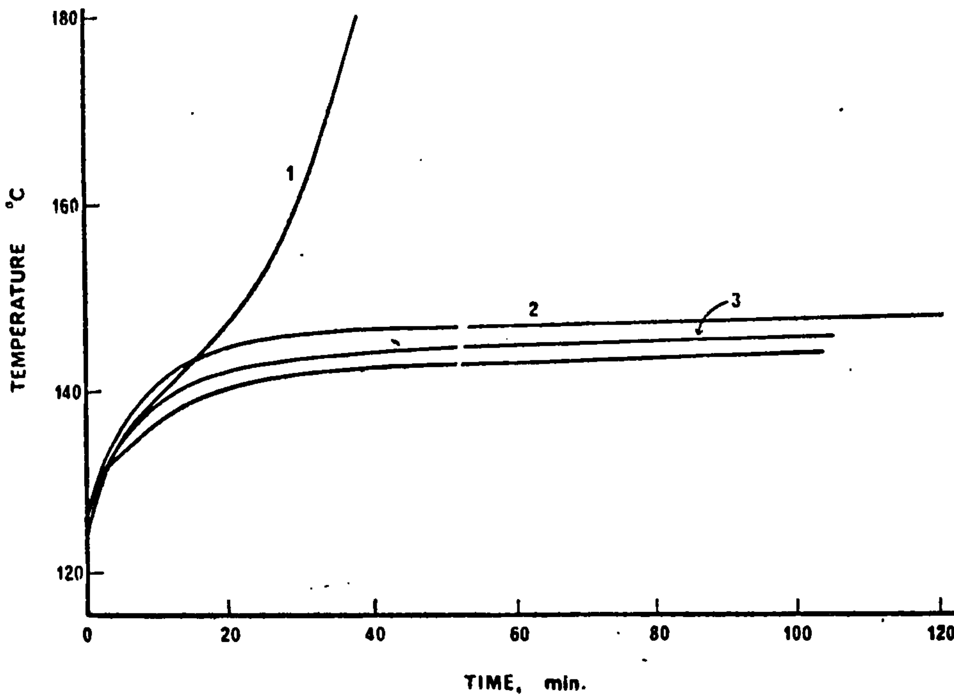

Fig. 6

REVERSION RESISTANCE

PERCENTAGE RETENTION OF MODULUS AFTER 1HOUR AT 180°C ON RHEOMETER

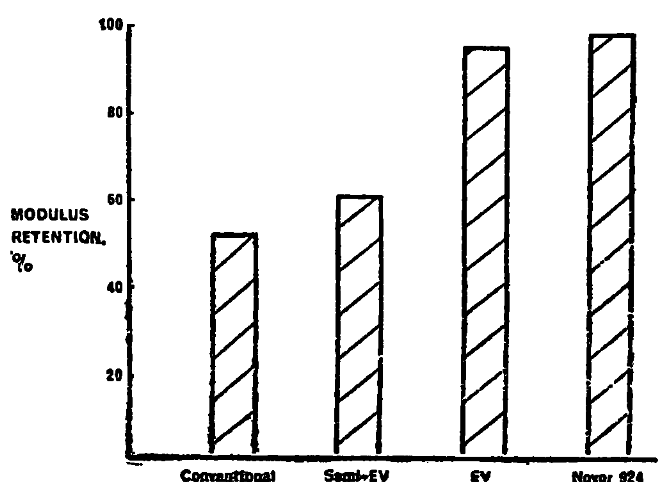

Fig. 7

Powdered Rubber : Powdered rubbers are not new, but up to now, their use has been largely confined to the adhesives industry. The prospect however is of powdered rubber being handled in bulk with continuous loading and unloading into containers, storage silos and ships holds saving labour and reducing transport costs and in the factory being metered with other compounding ingredients into rapid and low cost powder mixers and continuously fed to the hoppers of continuous mixer-extruders or injection moulding machines, again with a saving of labour, energy and reduced complexity of operations. Capital costs would be greatly reduced by the elimination of conventional warehouses, fork-lift trucks, internal mixers, sheet-off mills and so on.

This picture will not be realised in the near future. The economic advantages of powdered rubber technology are still uncertain. Powdered rubber will inevitably cost more than baled rubber and equivalent savings will have to be found in processing to justify its use.

Industrial use of powdered rubbers is still on a small scale. Full advantage will only be obtained, when brand new plants are designed around this form of rubber. In the meantime powdered rubbers have to be used in conventional mixing equipment but increases of throughput by two or more have been claimed.

However, in tyre factories with present low costs of mixing, the premium must be as low as 2 or 3 US Cts per lb if it is to be recovered by savings in labour and energy. Thus it is only in circumstances where a fractional increase in capacity of existing equipment is required (*e.g.* 1½ Banburys), or in special non-tyre applications, or in uses on the margin of the rubber industry that current premiums can be justified.

Nevertheless, natural rubber powder can not be dismissed out of hand. A radical development of new equipment involving lower capital costs could transform the scene. Many are firmly convinced that as existing equipment is progressively replaced by modernized machinery the development and use of powdered rubber and powdered masterbatches will lead to technical and economic advantages and that there will be increased profit from its use. But the development will take many years.

In this, it is evident that natural rubber must not lose out by default, a challenge is presented to natural rubber producers. They must attain a state of preparedness so that they can supply material — either rubber or rubber compounds — in a free-flowing form as powder, granules, crumbs, or pellets.

Liquid Rubbers : Liquid rubbers — liquid low molecular weight polymers which can be transformed by chain extension and crosslinking into products — possess similar advantages to powdered rubbers. They can be handled and stored in bulk and they lend themselves to continuous processing and to simpler methods of fabricating products with consequent savings in labour and energy and reduction of the complexity of operations and equipment.

Liquid castable polyurethanes have been used for twenty years or more, their major use is in foam but there is a steady growth in their use for solid and microcellular articles and in adhesives. They have recently been used on an experimental scale for the production of cast pneumatic tyres. Liquid butadiene, butadiene-styrene, and butadiene-acrylonitrile rubbers have also been developed. For most applications these rubbers require compounding with reinforcing fillers, then they become pastes and cannot be moulded by liquid casting techniques and an entirely new equipment and technology for processing is required. Further none of these liquid rubber exhibit satisfactory final properties equivalent to those obtainable from solid rubbers and prospects of liquid rubbers replacing solid rubber over a wide area of use appears poor.

Thermoplastic Rubbers : Thermoplastic rubbers bring a new concept to rubber processing; they eliminate the need to mix vulcanizing ingredients and the need to vulcanize. Thus there are savings in time, energy and capital costs, and scrap and rejects can be recycled.

The current consumption of thermoplastic rubbers is in the region of 50,000 tons a year. Most of the commercial types are block or graft copolymers, but a recently available type is a special blend of polymers. Both types behave at normal temperatures as if they were vulcanized materials, but they can be processed as thermoplastics at higher temperatures. A market in excess of 200,000 tons is predicted for the early 1980s and further rapid growth is envisaged.

The sophisticated molecular engineering during polymerization which is used to create these synthetic materials is not possible for natural rubber. But there are several possible ways in which thermoplastic natural rubber may be produced ; by the development of special graft copolymers, new thermolabile crosslinks, and specially blended mixtures of natural rubber with certain thermoplastics.

Progress is being made on all three fronts to meet a serious challenge to natural rubber in many applications.

NEW TYPES OF NATURAL RUBBER

Over the years special types of natural rubber have been developed to meet more fully consumer requirements for specific applications for example Superior Processing Rubber ; MG Rubber ; Constant Viscosity Rubber ; Tyre Rubber ; De-proteinised Rubber ; Pre-vulcanized Latex ; Low Ammonia Latices.

The demands for new types appear likely to increase and natural rubber producers must contemplate the need to provide types geared to the requirements of manufacturing processes. Obvious early contenders are masterbatches, pre-compounded rubbers, blends and application oriented latices for dipping, carpet backing and adhesives.

The natural rubber producing industry is not alone in facing challenges now and in the near future. The synthetic rubber producing industry has even greater challenges in front of it. It has profited from abundant supplies of a cheap feedstock, but now it is having to contend with escalating costs of its raw materials and possible limitations of their supply conserve the finite resources available. It is anticipated that within the next fifty years petrochemical feedstocks will become inadequate fully to meet demand and within the next hundred years the synthetic rubber industry will have had to transform completely to other sources of hydrocarbons.

Increasing concern for health, safety and the environment is already resulting in legislation regarding hazards and pollution. Inevitably this will lead to rising costs and may even result in the abandonment of the production of certain materials.

In contrast, provided adequate care is taken to maintain the soil, there will be a continuing and inexhaustible supply of natural rubber derived for solar energy, rain and carbon dioxide.

Thus, I think that you will all agree that although it is one hundred years since natural rubbers' incarnation — some say it is as old as Aunt Hattie — there is no visible sign of senile decay. There is no doubt that it will be able to meet and overcome the challenges which face it at the beginning of its second century. It is and will remain for the foreseeable future the cheapest source of rubber elasticity and in this age of energy conservation and crises and of increasing social awareness of the hazards of environmental pollution the fact that it is based on a non-polluting renewable resource lends credence to the use of the expression — Nature is on its side.