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UNIDO Project for the Development of Natural Rubber-based Truck Tyre Retreading Materials

Final Report
October 1992

MALAYSIAN RUBBER RESEARCH & DEVELOPMENT BOARD

Contract No. 88/81

UNIDO PROJECT NO. US/GLO/85/068

DEVELOPMENT OF NATURAL RUBBER-BASED TRUCK TYRE RETREADING MATERIALS

FINAL REPORT

from the Contractor,

The Malaysian Rubber Research and Development Board

to

The United Nations Industrial Development Organization

October 1992

ABSTRACT

The Contract has been concluded with the completion of all aspects of the work undertaken. This Final Report contains the Seventh Progress Report and a Final Project Summary, together with Recommendations for Future Action based on the results of the Concluding Workshop.

The Final Progress Report gives details of the participation of IRRDB Member Institutes and the training of their staff in modern precured retreading techniques. Results of all the second-stage trials are presented, together with the results of other tests on wet grip and rolling resistance.

The Project Summary reviews the results in terms of the initial objectives, their proposed implementation and expected outputs as defined in the Project Proposal, dealing first with the objective of training and technology transfer. This has resulted in direct contacts for the first time between some Institutes and the retreading industries in their countries, with efforts to improve existing retreading technology.

The technological objectives of the Project have been fully met. A commercial truck tyre retreading plant was established and operated successfully to produce almost 2000 retreads. Road wear trials of experimental natural rubber-based tread compounds against a very high quality all-synthetic control have been completed in six countries with very satisfactory results. In all of the countries, at least one of the natural rubber-based compounds gave wear results within about 10% of that of the control. Definite evidence was obtained for the improved performance of formulations containing higher than normal levels of stearic acid under low severity wear conditions. The improved wet grip and rolling resistance of the natural rubber-based retread compounds suggests that they can be economically competitive with all-synthetic retreads.

Recommendations for Future Action are made, based on the results of the Concluding Workshop held in February 1992.

CONTENTS

1 INTRODUCTION

1.1 Background

Work began on the Project in October 1988. It involved active participation by ten member Institutes of the International Rubber Research and Development Board in the production of some 2000 retreaded truck tyres and their evaluation in six countries. The First Interim Report, December 1988, reviewed the Project background and work plan and described the installation of most of the factory-scale truck tyre retreading plant. The Second Interim Report, May 1989, described the final installation and commissioning of the retread plant, and the completion of arrangements for the participation of three of the IRRDB Institutes. The Third Interim Report, November 1989, described the completion of arrangements for two more IRRDB Fellowships, contained reports of the Fellows from India and Indonesia, and detailed the manufacture of precured treads, the integrity and performance testing of retreads manufactured on the plant, and preliminary results from trials of steel-belted radial retreads in India, Indonesia and Malaysia. The Fourth Interim Report, May 1990, covered the completion of the first stage of the IRRDB Training Fellowships, the manufacture of the retreads for the first stage road trials, assessment of the steel-belted radial trials and preliminary wear data from five of the six countries. The Fifth Interim Report (November 1990) covered the beginning of the second stage of IRRDB Training Fellowships, completion of the preliminary steel-belted radial trial, initiation of a multi-section retread trial, assessment of the first stage road wear trials, modification of the natural rubber-based formulations for the second-stage trials, changes in the retreading equipment to facilitate retreading of crossply tyres, and commencement of manufacture of the retreads with the modified compounds.

At this stage it became apparent that the wear trials would not be completed in time for the Final Report to be issued in October 1991. UNIDO therefore agreed to the extension of the Project for six months to February 1992 to allow time for the trials to be completed. It was agreed to present an additional Sixth Interim Report in September 1991. This Report dealt with the finalization of the IRRDB Training Fellowship scheme, two further Complementary Research Projects, final assessment of the multi-section retread trials and the first stage road wear trials, manufacture of retreads for the second stage road trials and preliminary wear results, and preliminary arrangements for the Concluding Workshop.

This Final Report comprises the Final Progress Report, the Final Project Summary and the Recommendations for Future Action based on the proceedings of the Concluding Workshop. The results presented in the Progress Report include:

a) the completion of the technology transfer programme with IRRDB Member Institutes,
b) the results of the Complementary Research Project carried out by the IRRDB Fellow from Vietnam,
c) results of the second stage trials,
d) results of rolling resistance and wet traction tests.

2 PARTICIPATION BY OTHER INSTITUTES

2.1 Background

This Project was designed to provide the maximum opportunity for participation by IRRDB member Institutes in both the truck retread testing programme and the transfer of up-to-date retreading technology. Nine IRRDB Training Fellowships of three months each were provided: five were for Member Institutes in countries in which the trials were to be carried out, namely the Peoples' Republic of China, Cote d'Ivoire, India, Indonesia and Malaysia. The remaining Fellowships were provided for the IRRDB Member Institutes in Nigeria, Sri Lanka, Thailand and Vietnam.

In China, the retread trials were organized by the Beijing Research and Design Institute of the Rubber Industry (BRDIRI), which is not a member of IRRDB. As noted in the Fifth Interim Report, arrangements were made for a senior engineer of the BRDIRI to spend one month at TARL.

The final position with regard to participation by other Institutes is summarized below.

2.2 Retread trials

The first stage retread trials were successfully completed in all six countries, and the final assessment of the results presented in the Sixth Interim Report. The second stage tyre trials have now been completed in all the countries. Payments of US$18 000 have been made to each of the Institutes supervising the trials to cover the cost incurred.

Despite the complexity of the operation, the supervision of the trials was generally carried out successfully. Delays in obtaining the results were relatively few, and the Trial Co-ordinators and their Institutes are to be congratulated on the way in which the results were achieved.

2.3 Technology transfer to IRRDB Member Institutes

The second stage of the technology transfer exercise has been successfully completed. All of the nominated Fellows have received the planned training and have submitted Training Reports. The last of these, from the Fellow from the Rubber Research Institute of Vietnam, is attached as Appendix 1 to this Report.

2.4 Technology transfer to industry

Apart from Malaysia, where the Rubber Research Institute has carried out research on truck tyre retreading for many years, most of the IRRDB Member Institutes have previously had little or no experience of truck tyre retreading, or regular contact with the local retreading industry. Involvement in this Project has provided them with the background knowledge necessary for meaningful dialogue with commercial retreaders and truck fleet operators. All have either taken the opportunity to initiate the process of technology transfer to local retreaders where they exist, or conducted surveys to establish the current status of the industry in their country. The following summary of the initiatives produced by the technology transfer phase of the Project is based on the papers presented at the Concluding Workshop.

2.4.1 China

As noted elsewhere, the retreading industry is serviced by the Beijing Research and Design Institute of the Rubber Industry, which carried out the road trials and which is not a member of the IRRDB. The IRRDB Member Institute, the South China Academy of Tropical Crops has collaborated with the Guangzhou Xingqiu Tyre Factory to produce a survey of the retreading industry in China. This has identified a marked trend towards the use of synthetic rubber in truck tyre retreading, which is almost exclusively carried out by the hot cap process. Tread life of 70–80% of that of new tyres is generally obtained and strenuous efforts are being made through the Monitoring and Testing Centre of the Ministry of Chemical Industry to improve quality.

The survey ascribed the virtual absence of precured retreading to the prevalence of severe carcass damage. Road improvements are reducing carcass damage and allowing increased use of radial tyres. Three precured retread production lines are now in operation and other factories are studying the process. The total potential retread market is estimated at 8 million tyres, although current production is 3.3 million.

2.4.2 Cote d'Ivoire

A survey carried out by the Institut de Recherches sur le Caoutchouc has shown that there is currently little truck tyre retreading in Cote d'Ivoire, with only two companies, both using the hot cap process and working under capacity. Problems centre on the lack of good quality casings; truck tyres are entirely radial ply, and road conditions and usage cause extensive carcass damage. However, the high cost of new tyres, all of which must be imported, provides the incentive for the establishment of a larger retreading industry. This would fit in with the Ivorienne Government's wish to increase local natural rubber consumption. An export market for retreads exists in neighbouring countries.

The Ministry of Industry in a joint study with the local UNDP office has identified truck retreading as requiring encouragement, and the IRRDB Institute is now in a position to provide assistance in achieving this objective.

2.4.3 India

The survey presented at the Concluding Workshop shows that the retreading industry is well-established, using both hot cap and precured processes. In 1989–90 it consumed almost 32 000 tonnes of total rubber, making it the fifth largest consuming sector. The proportion of precured retreading is expected to grow significantly in the next few years, encouraged by a change from crossply to radial ply tyre usage. However, price considerations are expected to maintain hot cap retreading at a high level.

Notwithstanding the developments already made, the industry is carrying out research and development on vulcanization time reduction, low temperature bonding gums and the precured retreading of off-the-road tyres. The Rubber Research Institute is now in a better position to assist in this work.

2.4.4 Indonesia

The Indonesian truck retreading industry is well established. The survey presented at the Concluding Workshop estimated that there are 116 retreading factories, of which eight use the precured retreading process. The total output is some 3.3 million retreads, representing 75% of production capacity; the lack of retreadable casings is the reason for the under utilization of existing capacity.

The Indonesian Tyre Retreaders Association was formed in 1990, and efforts are being made to improve retread quality as public acceptance of retreaded tyres is increasing. There is little interest by most retreaders in changing from hot cap to precured retreading because of lack of experience and a consequent reluctance to invest in the new technology. The Bogor Research Institute for Estate Crops is now in a position to provide information on modern precured retreading technology.

2.4.5 Malaysia

The Malaysian tyre retreading industry is a thriving and progressive one, and has contributed significantly towards the country's economic well-being. The industry produces just over 2 million retreaded tyres of all types and consumes 11 700 tons of raw rubber annually, ranking third among the various dry rubber product sectors, and accounting for 15% of the rubber consumed by these sectors. This output is provided by approximately 100 retreaders, some with outputs of 400–500 tyres/day being large by international standards.

Precured retreading is almost entirely used for heavy truck tyres. It was introduced during the late 1970s and began to increase in popularity after 1984. The introduction of all-synthetic precured treads into Malaysia by the franchising system provided an added impetus which helped to accelerate its acceptance. The Malaysian retreading industry responded by improving its general quality level and by introducing natural rubber-based precured treads, which in some cases have achieved export markets in Europe, the Middle East, Oceania countries and the Far East.

The Malaysian Association of Tyre Retreaders and Dealers Societies has taken positive steps towards achieving ethical professional practice among its members and in educating the consuming public to eradicate the misconceptions about the quality of retreads. The industry has pioneered the adoption of ISO 9002 quality assurance systems, and is the single largest industrial sector to have conformed to this standard.

For the past few years the industry has been consolidating, with the smaller, less quality conscious retreaders being phased out of business as a result of their inability to up-grade themselves in terms of equipment and to reduce cost through improved productivity. This has resulted in a gradual increase in the average size of a retreading unit. At the same time, some retreaders are also integrating vertically to produce their own compounds and to provide vehicle and tyre servicing.

The last few years have also witnessed tremendous expansion and aggressive export drive among the Malaysian rubber product manufacturers, including those engaged in the tyre compounding and retreading business. The requirements to achieve ISO 9002 standards for export, together with increasing local quality awareness among government tender bodies and institutional buyers, have increased pressure for quality assurance systems. The diffusion of quality assurance systems into retread-related sectors, especially the compounding sector, would provide the basis for a general uplift in the quality level of retreads. The Rubber Research Institute of Malaysia is uniquely well placed to assist the compounding and retreading industries to achieve this objective.

2.4.6 Nigeria

The Rubber Research Institute of Nigeria instituted a nationwide survey of the retreading industry. From information obtained in two of the country's four zones, it was clearly established that the considerable potential for a retreading industry has yet to be exploited. There are probably only six small retreading companies using old equipment. Tyres are usually run to destruction, with a large proportion regrooved by small operators.

On completion of the survey the Institute will be in a position to assess fully the action needed to establish a viable truck tyre retreading industry, and assist in providing the necessary education for retreaders and truck operators through the organization of Workshops.

2.4.7 Sri Lanka

Retreading of passenger car tyres was introduced into Sri Lanka as long ago as the early 1930s, and truck retreading began with the servicing of military vehicles in the Second World War. Kelani Tyres (Pvt) Ltd, set up as the Sri Lanka Tyre Corporation in 1967, can supply only about half of the new tyres required and there is a well-developed retreading industry. The major retreading company has recently introduced precured retreading and has announced plans for the development of the industry on a franchise basis. Nevertheless, there are still a number of small retreaders producing low-quality retreads.

The Rubber Research Institute of Sri Lanka organized a one-day Seminar in Colombo on Tyre Retreading in September 1991. The papers covered the general aspects and economics of retreading, as well as the use of specific materials. The IRRDB Fellow presented two of the papers on 'General Aspects of tyre retreading' and 'Precured retreading'. Two training videos were also shown. In addition, the Fellow has published a paper on 'Use of natural rubber in tyres' in the *Journal of the Plastics and Rubber Institute of Sri Lanka.*

A problem identified in the retreading industry in Sri Lanka is the practice of using scrap rubber as one of the raw materials. The Institute has therefore initiated a project on 'Evaluation of the performance of scrap rubber in tyre retread compounds'. It is proposed to use the data collected to demonstrate to the local industry the unsuitability of this poor quality rubber for use in retreading.

2.4.8 Thailand

The survey by the Rubber Research Institute of Thailand has shown that truck tyre retreading is well established in Thailand, with precured retreading having been introduced almost twenty years ago. Natural rubber is extensively used in precured retreading, which is now operated at four of the 40 retreading factories. Two of these are major producers, manufacturing in excess of 1000 retreads and consuming over 200 tonnes of natural rubber every month.

The Institute has taken the initiative in promoting the further use of precured retreading by the publication of a paper on this subject in the *Para Rubber Bulletin*, and by including a lecture on 'The precured retreading process' in the 3-month intensive training course on rubber technology provided for employees in the rubber manufacturing industry.

2.4.9 Vietnam

The survey conducted by the Rubber Research Institute of Vietnam has shown that there are only eight truck tyre retreading factories, producing about 160 000 retreads/year. No new tyres are manufactured in Vietnam, and there is considerable potential for expanding the truck tyre retreading industry which suffers from lack of investment and outdated machinery. The retreading industry uses only natural rubber and the hot cap retreading process.

The Rubber Research Institute has established contacts with the retreaders with the objective of introducing precured retreading technology and improved retread compounds based on those developed in the Project. As a result, one company has ordered a precured retreading plant which should be installed in mid-1992.

2.4.10 Conclusion

All of the IRRDB Institutes participating in the Project now have contacts with the local retreading industries and where these contacts did not previously exist, surveys of the industry have been carried out. In all cases the use of precured retreading technology is being actively supported or promoted, together with the use of improved formulations. In those countries without adequate retreading facilities, the Institutes have initiated moves to introduce or upgrade the industry.

It can be concluded that participation in the Project has successfully stimulated the interest of the IRRDB Member Institutes in modern precured truck tyre retreading technology, and positive steps are being taken in all the countries to improve or introduce this technology in the local rubber manufacturing industries.

2.5 Concluding Workshop

The Concluding Workshop was held on 11–13 February 1992 in Kuala Lumpur, as described in Section 7 of this Report. Eleven IRRDB Institutes were represented, all of the IRRDB Fellows being present. Papers were presented on the status of the truck tyre retreading industries in ten countries. The complete Proceedings of the Workshop will be published in late 1992.

2.6 Summary

The training and technology transfer exercises provided for by the IRRDB Training Fellowships have been successfully completed. The training provided has encouraged many of the IRRDB Institutes to make contact for the first time with the local retreading industry, and the process of technology transfer from the Institutes to the retread manufacturers has been initiated.

3 TRAINING OF IRRDB FELLOWS

3.1 Objective

As indicated in the previous Reports, the training programme had three objectives: to familiarize the Fellow with the techniques necessary for the successful establishment and control of a road trial; to provide training in all aspects of up-to-date truck tyre retreading technology; and to provide an opportunity for the Fellow to carry out a specific research project on a subject complementary to the main programme.

3.2 Reports

Each Fellow was required to produce a full report of the Complementary Research Project, and a complete report of their training period. The last of the Complementary Research Projects, by Mr Tho Nguyen, is described in Section 4 of this Report, and his Training Report is given as an Appendix.

3.3 Summary

The training programme has now been completed. The success achieved in transferring the most modern technology associated with truck tyre retreading and testing has been demonstrated by the activities of the Institutes reported in the preceding Section.

4 COMPLEMENTARY RESEARCH PROJECT G: SERVICE WET TRACTION TESTING OF UNIDO TRUCK TYRE RETREAD COMPOUNDS

Tho Nguyen

4.1 Introduction

In Complementary Research Projects E and F (Fifth and Sixth Interim Reports), a prediction of the wet skid resistance of the UNIDO retread compounds was made by use of the British Road Research Laboratory pendulum skid tester. This portable skid tester was originally developed for measuring the wet skid ratings of highway surfaces[1]. In recent years it has been used with some success to predict the wet traction performance of tread compounds. However, it is now apparent that the nature of this test does not allow discrimination to be made between compounds having similar wet traction characteristics. The results given in research projects E and F are somewhat contradictory.

There is in fact no universally recognized method for measuring the wet traction of truck tyre compounds on actual truck tyres. For passenger car tyres, direct measurements of wet traction can be made safely on special test tracks using either skid path length or breakaway testing. Direct measurements on trucks are not carried out because of the danger associated with subjecting large vehicles to these types of tests.

The method usually adopted for truck tyres involves using the above standard tests on passenger car tyres retreaded with the appropriate truck tyre retread compounds. This procedure has been adopted here.

4.2 Experimental

4.2.1 Mixing

The compound formulations are shown in Table 1. The natural rubber, SMR 20, was premasticated to a Mooney viscosity (ML 1+4) at 100°C of 65. The raw rubbers and compounding ingredients were mixed in a Francis Shaw *K2A Intermix* (30kg) at 50rev/min starting at 80°C, 80psi ram pressure and cooling water at 9000l/h. The mixing cycle was:

0 min	add polymers, antidegradants, zinc oxide and stearic acid
0.5 min	add filler and oil
2.0 min	sweep
4.0 min	sweep
5.5 min	discharge at 125°C

After maturation curatives were added in a final pass of 2.0min.

4.2.2 Mix properties

After conditioning of the compounds for 24 hours, the scorch time at 120°C was determined using a Sondes Place Mooney viscometer and the rheological properties at 150°C were measured on a Monsanto *R100 Rheometer*.

4.2.3 Preparation of test samples and physical testing

The samples for the physical tests were vulcanized in a steam-heated hydraulic press at 150°C. The vulcanization time was t_{95} for each compound. The vulcanizate properties were tested according to the following standard methods:

Property	Test Method
Resilience (Dunlop Tripsometer)	BS903 Part A8
Hardness (IRHD)	BS903 Part A26
Relaxed modulus	BS1673 Part 4
Tensile properties	BS903 Part A2
Abrasion resistance (DIN)	ISO 4649

The aged properties of the compounds were evaluated on test samples after 14 days at 70°C in a circulating air oven.

4.2.4 Retreading

The mixes were remilled prior to the finalization stage to ensure the Mooney viscosity of 45–50 necessary for processing on an AMF *Orbitread* tyre building machine (series 200C). New 165x13 steel radials, whose tread had been buffed off, were retreaded in a conventional bead-to-bead remoulding press at 150°C.

4.2.5 Wet traction testing

The tyres under test were fitted to a two-wheel Schallamach trailer (weight 2227lbs). For these tests, the wheels were set at zero slip angle. A compressed air cylinder provided power to the trailer brakes, which were operated electrically and were independent from the brakes of the towing vehicle. The testing was carried out at the Transport and Road Research Laboratory's wet grip straight line braking facility where the surfaces were watered with a spray and weir system. Skid path lengths after applying the brakes on the trailer were recorded using a distance counter located on the towing vehicle.

4.3 Results and discussion

The cure characteristics of the compounds and the physical properties of the unaged and aged vulcanizates are shown in Table 1. The relative skid ratings measured on the BRRL skid tester (described in the Sixth Interim Report) are given in Table 2. The results of the wet traction tests at three speeds on a motorway asphalt surface are given in Table 3. The laboratory wet skid results are broadly in line with those reported in Complementary Research Project F.

Surprisingly, the service wet traction results (Table 3) appear to show even less discrimination between the compounds when compared to the laboratory data. However, there is confirmation that the optimum compound for wet traction is the natural rubber/SBR blend, whilst the 100% natural rubber compound, overall, is slightly the worst. Although 100% natural rubber compounds have been accepted for many years as having acceptable wet traction properties for *truck tyres*, clearly any improvements will be welcomed by the industry.

4.4 Conclusions

Although the service wet traction trials appeared to show smaller differences between compounds when compared with the laboratory data, the differences are highly significant in real driving terms. The natural rubber/SBR blend has substantially better wet traction characteristics than the other UNIDO tread compounds.

4.5 Reference

1. Giles, C.G., Sabey, B.E., and Cardew, K.H.F., Development and performance of the Portable Skid Resistance Tester. Symposium on Skid Resistance, ASTM Special Technical Publication, 1962, 50, No. 326.

Table 4.1.
Second stage trial retread formulations

Formulation	1	2	3	4	5
Natural rubber, SMR 20	–	65	100	65	65
SBR 1712	55	48.1	–	–	–
SBR 1500	25	–	–	–	–
High Cis BR	35	–	–	–	–
OEBR	–	–	–	48.1	48.1
Struktol A82	–	1	1	1	1
ISAF, N234 black	55	55	50	55	55
Process oil [a]	–	2	5	2	2
Zinc oxide	4	4	4	4	4
Stearic acid	2	2	2	2	6
Santoflex 13	2	2	2	2	2
Santocure MOR	0.8	0.8	0.8	0.8	0.8
Sulphur	2.2	2.2	2.2	2.2	2.2
Rheological properties					
Mooney scorch, t_5, 120°C, min	48	41	27	32	36
Monsanto Rheometer, 150°C, 1° arc, range 50					
ML, torque units[b]	17.5	15.0	14.0	15.5	13.5
MHR, torque units	77.5	68.0	68.0	67.0	68.0
t_{s1}, min	7.0	6.0	4.0	4.5	5.0
t_{90}, min	27	17	13	16	17
t_{95}, min	32	20	15	18	20
Unaged physical properties at t_{95}					
Hardness, IRHD	68	68	66	66	69
MR100, MPa	2.18	2.09	2.06	1.68	2.27
tensile strength, MPa	24.3	26.4	28.2	23.3	24.5
M100, MPa	2.33	2.21	2.24	1.75	2.33
M300, MPa	11.9	12.0	12.2	9.18	12.0
Elongation at break, %	518	554	560	575	508
Abrasion index					
DIN	129	94	93	104	110
Akron	238	145	130	165	178
Resilience, Dunlop, %					
23°C	54.2	51.7	59.8	59.2	60.1
40°C	59.1	59.0	65.6	63.8	64.2
60°C	63.3	63.0	68.7	65,.9	66.8
80°C	65.8	66.2	70.7	68.0	68.8
100°C	69.9	69.3	73.2	70.7	71.8
Goodrich *Flexometer*, static stress 1MPa, stroke 4.445mm, frequency 30Hz, start					
temperature rise after 30min, °C	63	56	47	56	51
set %	4.17	5.68	6.36	7.25	5.11
static stress 1MPa, stroke 5.715mm, frequency 30 Hz, start 23°C					
temperature rise after 30min, °C	92	77	69	95	64
set %	13.6	15.8	13.9	F	9.51
After air oven ageing for 14 days at 70°C					
Hardness, IRHD	74	73	70	69	73
Tensile strength, MPa	21.4	23.2	26.9	22.3	22.5
M100, MPa	3.48	3.12	2.98	2.31	2.93
M300, MPa	16.5	15.2	14.7	11.6	14.4
Elongation at break, %	383	445	502	497	435

a. Dutrex 729, Shell Chemicals.

b. 1 torque unit = 0.05Nm.

Table 4.2.
Skid ratings[a] measured on BRRL skid tester

Compound	Rating
SBR/BR[b]	100
NR/SBR	104.6
NR	91.7
NR/BR	96.3

a. 100 x skid resistance of test compound/skid resistance of control.
b. Control.

Table 4.3.
Service wet traction ratings on a motorway asphalt surface

Speed, mile/h	SBR/BR[a]	NR/SBR	NR	NR/BR	NR/BR/HS
25	100	103.9	98.8	101.1	100.1
35	100	104.6	100	101	99.1
45	100	104.3	99.1	99.6	101

a. Control.

5 SECOND STAGE WEAR TRIALS

5.1 Introduction

The second stage wear trials are either completed or nearing completion in all six participating countries.

The selection of compounds and the casing construction used for each country has been discussed in previous Reports. Crossply retreads were used for the trials in China, India, Indonesia and Malaysia, and steel-belted radial retreads in Cote d'Ivoire and the United Kingdom, according to local practices. Analysis of the first stage trials clearly demonstrated that the performance of the experimental retreads was highly country dependent.

The analysis of the first stage trials showed conclusively that the environmental conditions in each country had a very large effect on the wear performance of identical tread compounds. The results of the second stage trials have therefore been assessed for each individual country, rather than making overall wear comparisons.

5.2 Crossply retread trials

5.2.1 China

5.2.1.1 Test vehicles

Three test fleets were chosen for the trials, each involving 15 vehicles. The details of two of the test fleets, Shao Guan and Yang Chun, were given in the Fourth Interim Report. The third test fleet, Guangzhou, involves similar vehicles to the Shao Guan fleet.

The conditions of service and location of the three test fleets are similar, but the Shao Guan fleet, in these trials, operated on some hilly land and mountainous terrain. The Yang Chun and Guangzhou fleets operated on mainly hilly land but no mountainous areas. The daily mileages were large and the wear rate of the tyres generally high. Other conditions of service and the meteorological environment were detailed in the Fourth Interim Report.

5.2.1.2 Wear data

Assessment of the wear data in China was somewhat complicated owing to a large number of retread failures, 20 in total. In some cases spares provided were not utilized. It will be observed that some of the final mileages quoted in Table 5.1 are much lower than the projected lifetime of the tyres; the reason for this being that the quoted figures are the last available wear results when all four test tyres were present on the vehicle.

Regarding the failures, two were attributed to immediate tread separation, and seven to punctures. The remaining eleven failed after distances of over 45 000km and could only be attributed to the quality of the original casing. The problems relating to the availability of suitable casings has already been discussed in earlier reports.

The relative wear ratings (Table 5.1) illustrate the difference in service conditions between the Shao Guan test fleet and the Guangzhou/Yang Chun test fleets. The severity of operation is clearly much higher for the Shao Guan fleet, resulting in an excellent performance by the all-natural rubber tread compound.

Unfortunately the number of failures precludes an accurate assessment of the change in relative wear ratings of the experimental compounds throughout the tyre life. However, indications are that both the natural rubber and the NR/BR/HS tread compounds improve in relative wear rating with increasing tread wear.

5.2.2 India

5.2.2.1 Test vehicles

Owing to the difficulty of locating even medium-sized fleets in the area of Kottayam, the majority of the 'fleets' selected, all buses of the Ashok Leyland type, consisted of either one or two vehicles. The conditions of service and location of the vehicles were very similar, although a few vehicles encountered some slight hilly terrain.

5.2.2.2 Wear data

The wear results for the individual vehicles are shown in Table 5.3 and the relative wear ratings in Table 5.4. The wear results clearly demonstrate that the severity of operation experienced by every vehicle is very high. Under such high severities it is sometimes difficult to distinguish between compounds. However, the performance of the 100% natural rubber compound would normally be expected to be superior to the all-synthetic compound. An analysis of the wear performance of one particular vehicle gives an insight into the apparent inferior performance of the natural rubber compound (Table 5.5). In the early stages of the tyre life the relative wear rating of the natural rubber compound is far superior to the control. As the tread wear progresses the wear rate of the control improves from 15.06×10^{-4}km/mm to 8.23×10^{-4}km/mm, whereas that of the natural rubber compound only improves from 11.97×10^{-4}km/mm to 8.32×10^{-4}. In fact, the *actual* wear rate of the control improves by a far greater amount, to around 6.14×10^{-4}km/mm, *ie* to about 41% of the initial wear rate. The result is that the relative wear rating of the natural rubber compound decreases from 125.8% initially to 98.9% at the end of the tyre life. Similar observations can be observed for most of the vehicles testing the natural rubber compound.

This decrease of relative wear rating of the natural rubber compound with increasing tyre wear is probably caused by reversion and oxidative ageing. It was observed that the hardness of the synthetic control fell from an initial value of 68 IRHD to 64 IRHD at the end of the tread life. The all-natural rubber tread hardness fell 10 points from 64 IRHD to 54 IRHD. However, the changes in hardness of the NR/SBR and NR/BR/HS experimental compounds are similar to the control, and the decreases in relative wear rating as the wear progresses are much less dramatic than for the natural rubber compound (Figure 5.1).

5.2.3 Indonesia

5.2.3.1 Test fleets

Three test fleets were chosen for the trials, which involved a total of 144 tyres. The remaining tyres (36) were reserved for future testing if the number of failures during service was not high. Of the three test fleets, two were bus fleets, operating under essentially low severity conditions and the third was a truck fleet operating under medium severity conditions.

5.2.3.2 Wear data

The wear data are given in Table 5.6, and show the different wear severities associated with the bus fleets, which are analysed together, and the truck fleet. The relative wear ratings are given in Table 5.7.

At both low and medium severities, the NR/SBR compound shows excellent wear performance which is very close to that of the all-synthetic control. Analysis of the wear performance of this compound throughout the tread life of the tyres shows that the relative wear rating does not change significantly as tread wear progresses (Figure 5.2).

The performance of the natural rubber compound requires closer analysis. The results appear inconsistent as the natural rubber compound should give better performance under the medium severity conditions of the truck fleet. However, the relative wear rating does not change significantly as tread wear progresses for the tyres on the bus fleet, but does in the case of the truck fleet. Here the relative wear rating decreases with increasing tread life, probably because of greater heat build-up during service, causing reversion of the natural rubber tread (Figure 5.2).

Analysis of the performance of the high stearic acid formulation clearly demonstrates one of the original concepts behind the Project, namely that a high level of stearic acid leads to improved reversion, and hence longer life, for tyre treads operating under low severity conditions. Figure 5.2 shows that for the bus fleets the relative wear rating improves substantially as the tyres approach the end of their wear life; the data used in the Figure relate only to those tyres which are almost completely worn. The average relative wear rating for the high stearic acid compound on the bus fleets, currently at 85.9 (Table 5.6), is expected to increase as more of the tyres approach full tread life. On the truck fleet the effect of stearic acid is far less pronounced, but is still apparent.

5.2.4 Malaysia

5.2.4.1 Test vehicles

Four test fleets were selected for the trials, two bus and two truck fleets. Unlike China, both bus and truck fleets operated under a broad spectrum of medium wear severities, from 1.20mm/10 000km to approximately 3.50mm/10 000km overall wear rate (Table 5.8).

5.2.4.2 Wear data

Unlike China, India and Indonesia, the majority of the tyres for the given vehicles were not rotated from near-side to off-side. There were also a surprising number of failures, in total 36. The reasons for failure were varied, including tread separations, punctures, casing failures, excessive groove cracking and excessive chunking. The higher service running temperatures of the control (SBR/BR) and the natural rubber/SBR compounds may have contributed to the overall failure rate: of 23 failures occurring before 50% tread wear, 20 were with these two compounds. The results reported in Table 5.9 refer to the final relative wear ratings for the tyres on a given vehicle when all four tyres were present, *ie* before any failures. For many vehicles the last available data refers to tyres at approximately 25-50% tread life. In the case of the NR/BR/HS compounds only two vehicles are beyond 75% tyre tread wear life. This precludes an accurate statistical assessment of change of relative wear rating with tread life. The relative wear ratings have been assessed by averaging the results for all the vehicles for a particular compound. Furthermore the results for each compound do not relate to an equal number of near-side and off-side control tests: wear rates are usually higher on near-side tyres. When the various stages of tyre life are also taken into account, the results must be treated with caution.

5.2.5 Summary

The results obtained show clearly that the performance of a particular tread compound is dependent not only on the level of wear severity but also on the environmental conditions. Under relatively high severity wear conditions, as in India, the all-natural rubber tread compound has given the closest match (96.5%) to the wear rate of the all-synthetic control retread. Under the less severe conditions the all-natural rubber compound gave the best comparison in China (87.9–96.5%), whereas in Indonesia the NR/SBR compound performed best (95.3–97.5%). The results obtained in Malaysia were disappointing, with only 90% of the control wear performance being recorded: this is significantly below the results obtained in the first stage trials for the natural rubber/synthetic rubber blends. The performance of the modified all-natural rubber compound used in the second stage trials was better than that obtained in the first stage trials in all countries.

5.3 Steel-belted radial retread trials

5.3.1 United Kingdom

5.3.1.1 Test vehicles

Several truck fleets were used in these trials, the majority being single drive-axle tractor units (articulated vehicles) operating under low severity wear conditions. The rest were either double drive-axle tractor units or tipper trucks operating at low to medium wear severity.

5.3.1.2 Wear data

The wear data is shown in Table 5.10, and illustrates that the majority of the vehicles are operating under low severity conditions with projected mileages of 120 000–250 000km.

The NR/SBR experimental tread compound exhibits excellent wear characteristics and matches the performance of the all-synthetic control compound (Table 5.11). Analysis of the results shows that, as in Indonesia, the relative wear rating of the NR/SBR compound remains constant throughout the life of the tyres (Figure 5.3). The data for the NR/BR compound shows an inferior wear performance compared to the control compound, and as for the NR/SBR compound, its relative wear rating remains reasonably constant as tread wear progresses (Figure 5.3).

The relative wear performance of the NR/BR/HS compound and its progression through the tread life of the tyres is consistent with the Indonesian data, showing that the high stearic acid level improves the reversion of the tread during service. The majority of the results quoted are still only at 70-75% tread life and are expected to improve by a further 2% by the time the treads are fully worn.

5.3.2 Cote d'Ivoire

5.3.2.1 Test vehicles

The majority of the fleets selected were bus fleets with individual journey distances of about 600km, although two buses travelled over 1000km to the neighbouring countries of Niger and Burkina Faso.

The number of vehicles originally fitted with the test retreads was 27, but four vehicles suffered immediate multiple tyre failures, and these tests were terminated. Throughout the trials there were about 30 tyre failures. There are probably two reasons for this high failure rate. First, the general road conditions in Cote d'Ivoire are not appropriate for the use of steel-belted radial tyres, although this is the only type of tyre construction used. Thus, although the general surfaces of the main roads are excellent – as shown by the general low severity wear conditions in this trial – all the vehicles travelled at some stage on very poor roads, where failures generally occurred. Second, the number of top quality casings of the particular size required available for purchase in Europe is very small. It is therefore possible that the casings were not of a sufficiently high standard to withstand the road conditions. Certainly there is a case for suggesting that the truck industry in Cote d'Ivoire would be much more cost effective if tyres of crossply construction were used. They would be cheaper than radial tyres, and would be far more likely to be in a suitable condition for retreading at the end of the first tread life.

5.3.2.2 Wear data

Because of the number of tyre failures, very few vehicles are beyond 60% tread wear life (Table 5.12). For this reason no accurate analysis for each compound is possible. However it is clear from Table 5.13 that the experimental compounds have performed well, all giving relative wear ratings above 92.

5.3.3 Summary

In both of the countries testing steel-belted radial tyres, one of the natural rubber-based compounds has given wear results within 4% of the all-synthetic control. The advantage of the high level of stearic acid is clearly apparent in the results for very low severity conditions in the United Kingdom.

5.4 Conclusions

The fleet trials have been successfully carried to completion in all six countries. In five of these countries at least one of the natural rubber-based tread materials gave wear results within 5% of the high quality all-synthetic rubber control. In the remaining country, Malaysia, the wear results were within 10% of the control, somewhat lower than in the first stage trials. In addition, the earlier suggestion that high levels of stearic acid are beneficial under conditions of low wear severity has been confirmed.

It has therefore been demonstrated that, with appropriate formulation adjustments for particular road and climatic conditions, natural rubber-based truck tyre retreading materials can match the best all-synthetic precured retread materials in terms of wear performance.

Table 5.1.
Results from second-stage trials in China

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km		Relative wear rating
		Control	Experimental	
Guangzhou test fleet				
NR/SBR	35 005	1.710	2.380	71.8
NR/SBR	34 532	1.920	2.185	87.9
NR/SBR	58 038	1.415	2.030	69.7
NR/SBR	57 926	1.795	1.865	96.2
NR/SBR	32 928	1.890	2.195	87.9
NR	66 181	1.480	1.640	90.2
NR	64 996	1.625	1.800	90.3
NR	62 270	1.640	1.950	84.1
NR	37 955	2.270	2.460	92.3
NR	49 926	2.010	2.240	89.7
NR/BR/HS	43 017	1.535	1.830	83.9
NR/BR/HS	43 412	1.860	2.225	83.6
NR/BR/HS	40 847	1.330	1.370	96.1
NR/BR/HS	57 352	1.525	1.875	81.3
NR/BR/HS	38 104	1.850	2.235	82.8
Shao Guan test fleet				
NR/SBR	31 045	2.350	2.300	102.2
NR/SBR	47 347	1.515	2.015	75.2
NR/SBR	31 150	2.425	2.600	93.3
NR/SBR	28 465	3.155	3.515	89.8
NR/SBR	36 162	2.480	3.275	75.7
NR	-			
NR	40519	1.760	2.230	78.9
NR	21 270	4.730	4.385	107.9
NR	29 278	3.620	3.450	104.9
NR	42 411	2.460	2.605	94.4
NR/BR/HS	34 649	3.360	4.080	89.0
NR/BR/HS	26 236	2.480	2.780	89.2
NR/BR/HS	41 855	2.980	3.520	84.7
NR/BR/HS	19 561	4.030	5.290	76.2
Yang Chun test fleet				
NR/SBR	64 359	1.695	1.830	92.6
NR/SBR	56 064	1.605	2.245	71.5
NR/SBR	52 099	1.790	1.820	98.4
NR/SBR	55 002	1.655	2.080	79.6
NR/SBR	35 738	1.555	1.975	78.7
NR	56 290	1.495	1.635	91.4
NR	47 307	2.085	2.205	94.6
NR	55 016	1.620	1.915	84.6
NR	37 840	1.680	1.930	87.0
NR	17 720	1.855	2.260	82.1
NR/BR/HS	51 616	1.710	2.450	69.8
NR/BR/HS	51 519	1.490	1.870	79.8
NR/BR/HS	55 146	1.805	2.025	89.1
NR/BR/HS	57 050	1.515	1.710	88.6
NR/BR/HS	35 512	1.420	1.715	82.8

Table 5.2.
Relative wear ratings for China

Tread type	Relative wear rating[a]		
	Guangzhou	Shao Guan	Yang Chun
NR/SBR	82.7	87.2	84.2
NR	89.3	96.5	87.9
NR/BR/HS	85.5	85.0	82.0

a. All-synthetic control = 100.

Table 5.3.
Results from second-stage trials in India

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km		Relative wear rating
		Control	Experimental	
NR/SBR	7 982	9.94	10.37	95.9
NR/SBR	9 572	12.24	14.24	86.0
NR/SBR	11 307	11.57	12.48	92.7
NR/SBR	11 226	9.95	11.90	83.6
NR/SBR	10 078	11.50	13.71	83.9
NR/SBR	7 152	13.05	14.02	93.1
NR/SBR	20 182	4.89	5.88	83.2
NR/SBR	21 604	4.81	5.35	89.9
NR/SBR	13 776	8.56	9.69	88.3
NR/SBR	13 071	9.85	10.50	93.8
NR/SBR	15 582	7.57	8.81	85.9
NR/SBR	9 404	9.32	10.15	91.8
NR/SBR	8 617	8.15	10.28	79.3
NR/SBR	9 223	9.88	12.03	82.1
NR/SBR	6 863	14.55	14.32	101.6
NR	13 460	6.64	7.79	85.2
NR	5 570	15.54	19.26	80.7
NR	11 596	9.79	10.84	90.3
NR	12 648	10.03	10.19	98.4
NR	12 750	10.85	11.10	97.7
NR	15 939	8.23	8.32	98.9
NR	11 252	11.89	12.14	97.9
NR	14 702	9.00	9.28	97.0
NR	11 468	11.16	9.99	111.7
NR	12 224	10.60	10.69	99.2
NR	8 372	11.67	11.57	100.9
NR	7 969	9.99	12.54	79.7
NR	6 695	13.05	14.96	87.2
NR	8 552	10.95	11.35	96.5
NR	6 303	14.77	16.63	88.8
NR/BR/HS	6 750	8.89	8.43	105.5
NR/BR/HS	10 097	10.45	11.90	87.8
NR/BR/HS	11 477	10.69	11.93	89.6
NR/BR/HS	11 458	10.82	11.31	95.7
NR/BR/HS	9 797	13.89	14.18	98.0
NR/BR/HS	13 267	8.93	10.03	89.0
NR/BR/HS	10 585	10.13	10.64	95.2
NR/BR/HS	12 284	11.38	11.14	102.2

Table cont...

Table 5.3. cont

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km		Relative wear rating
		Control	Experimental	
NR/BR/HS	9 957	8.37	9.76	85.8
NR/BR/HS	7 426	11.22	12.81	87.6
NR/BR/HS	8 598	9.35	9.73	96.1
NR/BR/HS	6 636	11.60	14.74	78.8
NR/BR/HS	7 443	12.47	14.19	87.9

Table 5.4.
Relative wear ratings for India

Tread type	Relative wear rating[a]
NR/SBR	88.7
NR	94.0
NR/BR/HS	92.7

a. All-synthetic control = 100.

Table 5.5.
Change of relative wear rating with tread wear, India.

Distance travelled, km	Wear rate $x10^4$, mm/km		Relative wear rate, %
	SBR/BR	NR	
2 164	15.06	11.97	125.8
4 882	11.72	10.29	113.9
7 302	10.22	9.50	107.6
9 618	9.73	9.43	103.2
13 530	8.60	8.68	99.1
15 939	8.23	8.32	98.9

Table 5.6.
Results from second-stage trials in Indonesia

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km		Relative wear rating
		Control	Experimental	
Bus fleets				
NR/SBR	95 163	1.001	1.103	90.8
NR/SBR	103 494	0.963	0.975	98.8
NR/SBR	87 641	0.904	1.097	82.4
NR/SBR	110 041	0.903	1.007	89.7
NR/SBR	93 416	1.403	1.020	137.5
NR/SBR	76 542	1.293	1.338	96.6
NR/SBR	57 819	1.214	1.160	104.7
NR/SBR	55 099	0.965	1.072	90.0
NR/SBR	88 988	1.280	1.477	86.7
NR	81 230	1.112	1.266	87.8
NR	94 557	0.968	1.041	93.0
NR	99 976	0.996	1.083	92.0
NR	84 152	1.016	1.127	90.2
NR	27 106	1.060	1.320	80.3

Table cont.

Table 5.6. cont

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km		Relative wear rating
		Control	Experimental	
NR	64 767	1.275	1.535	83.1
NR	55 040	1.085	1.391	78.0
NR	88 918	1.095	1.312	83.5
NR/BR/HS	114 626	1.000	1.062	94.2
NR/BR/HS	98 451	1.014	1.029	98.5
NR/BR/HS	78 229	0.932	1.124	82.9
NR/BR/HS	106 090	1.040	1.107	93.9
NR/BR/HS	37 214	1.025	1.135	90.3
NR/BR/HS	26 289	0.955	1.360	70.2
NR/BR/HS	63 242	1.005	1.115	90.1
NR/BR/HS	49 345	0.785	1.150	68.3
NR/BR/HS	65 035	1.420	1.680	84.5
Truck fleet				
NR/SBR	36 791	2.468	2.698	91.5
NR/SBR	37 030	2.500	2.501	99.9
NR/SBR	50 189	2.255	2.388	94.4
NR	52 419	2.242	2.619	85.6
NR	29 396	2.225	3.230	68.9
NR	25 569	2.145	3.100	69.2
NR/BR/HS	28 151	2.955	3.325	88.9
NR/BR/HS	49 335	2.300	2.640	87.1
NR/BR/HS	33 784	2.007	2.475	81.2

Table 5.7.

Relative wear ratings for Indonesia

Tread type	Relative wear rating[a]	
	Bus fleets	Truck fleet
NR/SBR	97.5	95.3
NR	86.0	74.6
NR/BR/HS	85.9	85.7

a. All-synthetic control = 100.

Table 5.8.
Results from second stage trials in Malaysia

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km		Relative wear rating
		Control	Experimental	
NR/SBR	56 830	1.603	1.656	96.8
NR/SBR	40 760	1.636	1.658	98.7
NR/SBR	40 446	2.504	2.604	96.2
NR/SBR	27 084	2.267	2.826	80.2
NR/SBR	21 982	2.141	2.479	86.4
NR/SBR	31 649	2.876	3.412	84.3
NR/SBR	60 447	1.283	1.275	100.6
NR/SBR	33 579	1.479	1.984	74.5
NR/SBR	38 466	1.478	1.433	103.1
NR/SBR	11 681	1.961	2.517	77.9
NR/SBR	53 771	1.979	2.106	94.0
NR/SBR	45 069	2.075	2.184	95.0
NR	28 459	2.690	3.534	76.1
NR	53 119	1.954	2.133	91.6
NR	60 371	1.616	1.912	84.5
NR	34 375	2.736	2.660	102.9
NR	40 407	2.096	2.650	79.1
NR	27 853	2.299	2.536	90.7
NR	57 084	1.269	1.811	70.1
NR	39 415	1.405	1.206	116.6
NR	63 785	1.160	1.267	91.6
NR	9 941	3.576	3.546	100.8
NR	48 578	1.209	1.382	87.5
NR/BR/HS	36 914	2.612	3.144	83.1
NR/BR/HS	22 169	2.109	3.182	66.3
NR/BR/HS	46 709	1.607	2.008	80.0
NR/BR/HS	60 159	1.589	2.008	79.1
NR/BR/HS	22 304	1.948	2.029	96.0
NR/BR/HS	27 798	2.561	3.037	84.3
NR/BR/HS	14 105	2.981	3.371	88.4
NR/BR/HS	53 249	1.231	1.500	82.0
NR/BR/HS	29 144	1.721	1.853	92.9
NR/BR/HS	10 529	3.229	2.659	121.4
NR/BR/HS	33 880	1.744	1.769	88.6

Table 5.9.
Relative wear ratings for Malaysia

Tread type	Relative wear rating[a]
NR/SBR	90.6
NR	90.1
NR/BR/HS	88.4

a. All-synthetic control = 100.

Table 5.10.
Results from second-stage trials in the United Kingdom

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km Control	Wear rate, mm/10 000km Experimental	Relative wear rating
NR/SBR	31 761	1.482	1.384	107.1
NR/SBR	31 761	1.023	1.132	90.4
NR/SBR	48 555	1.544	1.608	96.0
NR/SBR	48 555	1.413	1.372	102.8
NR/SBR	52 713	0.991	1.087	91.1
NR/SBR	67 274	1.192	1.332	89.5
NR/SBR	68 525	0.887	0.982	90.3
NR/SBR	82 681	1.196	1.345	88.9
NR/SBR	106 603	0.794	0.775	102.5
NR/SBR	112 794	0.634	0.596	106.4
NR/SBR	86 914	0.892	1.000	89.2
NR/SBR	117 347	0.754	0.705	107.0
NRBR	22 071	1.607	2.082	77.2
NRBR	32 176	1.111	1.401	79.3
NRBR	50 896	1.094	1.320	82.9
NR/BR	42 713	1.361	1.634	83.3
NR/BR	42 713	1.801	1.599	112.6
NR/BR	67 772	1.170	1.459	80.2
NR/BR	89 316	0.982	1.142	86.0
NR/BR	93 641	0.835	0.986	84.7
NR/BR	102 537	0.779	0.928	83.9
NR/BR	119 172	0.660	0.786	84.0
NR/BR/HS	31 303	1.636	1.840	88.9
NR/BR/HS	33 792	1.302	1.541	84.5
NR/BR/HS	33 604	0.845	1.069	79.0
NR/BR/HS	44 261	1.460	1.587	92.0
NR/BR/HS	44 261	1.986	1.966	101.0
NR/BR/HS	80 174	0.684	0.768	89.0
NR/BR/HS	87 493	0.726	0.854	85.0
NR/BR/HS	92 671	0.629	0.698	90.1
NR/BR/HS	94 303	0.792	0.899	88.1
NR/BR/HS	93 576	0.941	1.055	89.2
NR/BR/HS	109 524	0.692	0.759	91.1
NR/BR/HS	111 677	0.749	0.789	94.9

Table 5.11.
Relative wear ratings for the United Kingdom

Tread type	Relative wear rating[a]
NR/SBR	96.8
NR/BR	85.4
NR/BR/HS	89.4

a. All-synthetic control = 100.

Table 5.12.
Results from second stage trials in Cote d'Ivoire

Experimental tread type	Distance covered, km	Wear rate, mm/10 000km Control	Wear rate, mm/10 000km Experimental	Relative wear rating
NR/SBR	66 706	1.103	1.157	95.3
NR/SBR	69 659	1.231	1.027	119.9
NR/SBR	61 070	1.063	1.267	83.9
NR/SBR	54 976	1.082	0.974	111.1
NR/SBR	65 205	0.840	1.055	79.6
NR/SBR	22 986	1.960	2.600	75.4
NR/SBR	27 405	1.076	1.447	74.4
NR/SBR	65 205	1.080	1.128	95.7
NR/SBR	18 736	1.793	1.691	106.0
NR/BR	37 498	0.898	1.110	81.6
NR/BR	100 748	0.881	0.928	94.9
NR/BR	118 969	1.320	1.360	97.1
NR/BR	117 320	0.806	0.900	89.6
NR/BR	13 772	1.684	1.687	99.8
NR/BR	28 500	1.422	1.382	102.9
NR/BR	16 943	1.080	1.298	83.2
NR/BR	65 700	1.166	1.291	90.3
NR/BR/HS	27 706	2.725	3.267	83.4
NR/BR/HS	68 110	1.248	1.341	93.1
NR/BR/HS	12 650	2.011	2.284	88.0
NR/BR/HS	9 010	2.036	2.041	99.8
NR/BR/HS	43 810	1.308	1.372	95.3
NR/BR/HS	121 692	0.840	0.710	118.3

Table 5.13.
Relative wear ratings for Cote d'Ivoire

Tread type	Relative wear rating[a]
NR/SBR	93.5
NR/BR	92.4
BR/BR/HS	96.3

a. All-synthetic control = 100.

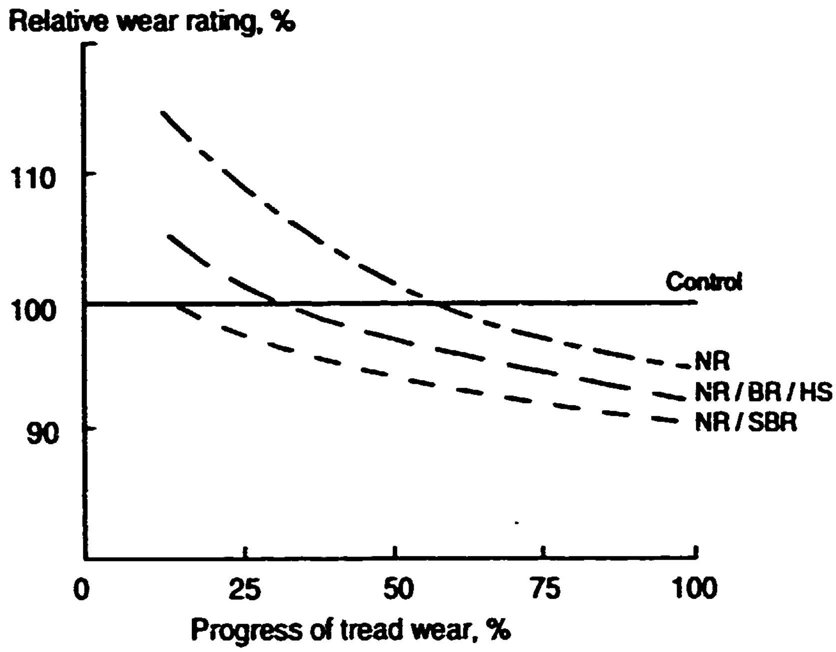


Figure 5.1 Change in relative wear rating in India.

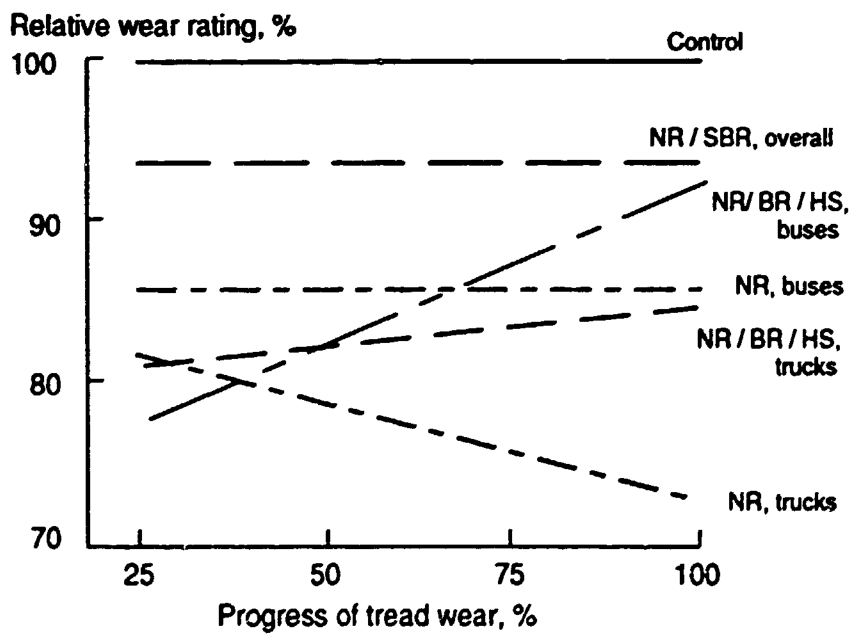


Figure 5.2 Change in relative wear rating in Indonesia.

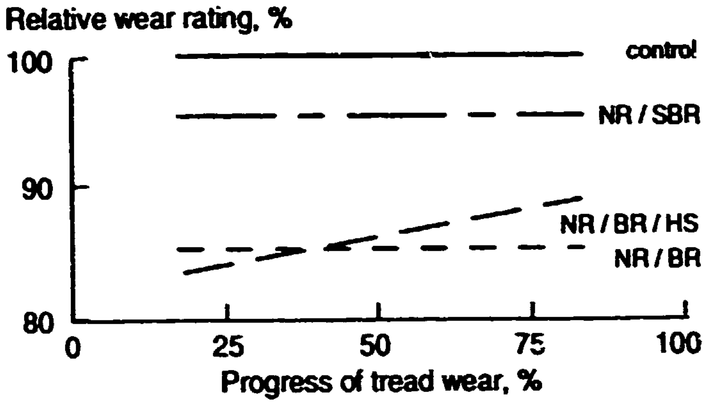


Figure 5.3 Change in relative wear rating in the UK.

6 ROLLING RESISTANCE AND TRACTION TESTS

6.1 Introduction

Fuel economy has become an increasingly important issue, and the tyre industry is very conscious of the need to contribute by reducing the rolling resistance of tyres. In fleet line operations the use of fuel saving devices can be easily identifiable as being cost effective[1]. The Goodyear Tire Company has published fuel consumption figures[2] for an 18-wheel truck, both empty and fully loaded. It was estimated that the tyres dissipated 25% of the mechanical energy available from the vehicle's fuel when it was empty, and 55% when it was loaded. Schuring and Futamura[3] showed that for an 18-wheel truck, a rolling resistance reduction of 10% is equivalent to a saving in fuel consumption of 3.94%.

Although fillers, process oils and cure systems, if optimized for a particular formulation, can have some effect on rolling resistance, the most important factor affecting this property is the choice of polymer. In this respect, natural rubber is the best choice since it has the lowest level of internal energy loss on deformation (hysteresis) of any of the large tonnage elastomers.

In Malaysia, for example, it has been shown[4] that the replacement of a 50:50 SBR/BR tread compound by a 50:50 NR/BR formulation leads to a 6% reduction in rolling resistance. The consequent fuel saving of around 2% will give cost savings equivalent to an improvement in tyre mileage of 15-20%. This final figure will vary from country to country and is dependent upon both fuel and tyre costs, but is extremely significant in the context of this Project.

Increasing concern over traffic safety in view of the tendency for vehicle speeds to increase has led to greater attention being paid to the wet traction performance of tyres. Wet traction is considered to be less of a problem for truck tyres than for passenger car tyres because of the generally lower speeds and higher ground contact pressures. However, in many industrialized countries truck speeds are very high, and wet traction will undoubtedly become of greater concern.

6.2 Experimental

6.2.1 Rolling resistance

For the rolling resistance tests, retreads of similar weight and overall dimensions were selected from the normal production schedule. The rolling resistance measurements for the first stage compounds were carried out using 9.00-20 cross-ply tyres at RRIM on a Mitsubishi laboratory road-wheel by the power measurement method. The rolling resistance of the tyre was measured as the power consumption of the machine with the tyre under load minus the power consumption with the tyre in skim contact with the drum.

The tyres were conditioned as follows:

speed	80km/h
load	100% rated load
inflation	690kPa (cold)
duration	4 hours.

They were then subjected to stationary thermal conditioning for 6 hours. Before the actual test the tyres were warmed by running them on the drum for 1.5 hours under the conditions given above.

The rolling resistance of the tyres was measured under the following conditions:

speed	20-100km/h
load	20-120% rated load
inflation	690kPa (cold).

The rolling resistance values of the tyres at 80km/h and 100% rated load are reported.

The rolling resistance measurements on the second stage compounds were carried out at MRPRA using 11R22.5 steel-belted radial tyres on a Heenan Froude test rig. In this case the torque measurement method was used, the rolling resistance of the tyres being obtained from the measured torque required to rotate the tyres under load minus the the torque measured for the tyre in skim contact with the wheel.

The tyres were conditioned as follows:

speed	32km/h
load	80% rated load
inflation	782kPa (cold)
duration	4 hours.

The rolling resistance was measured under the following conditions:

speed	32-59.2km/h
load	80-100% rated load
inflation	782kPa (cold).

The rolling resistance values of the tyres at 59.2km/h and 100% rated are reported.

6.2.2 Wet traction

There is no universally recognized method for measuring the wet traction of truck tyre compounds on actual truck tyres. For passenger car tyres, direct measurements of wet traction can be made safely on special test tracks using either skid path length or breakaway testing. Direct measurements on trucks are not carried out because of the danger of subjecting large vehicles to these tests. The method usually adopted for truck tyres involves using the standard tests on passenger car tyres retreaded with the appropriate truck tyre tread compounds. This procedure was adopted here.

The wet traction tests were carried out using new 165x13 steel radial tyres. The treads were removed by buffing and the carcasses retreaded using an AMF *Orbitread Series 200C* tyre building machine with the compounds masticated to Mooney viscosities of 40-50. They were vulcanized in a conventional bead-to-bead remoulding press at 150°C.

This work was carried out as a Complementary Research Project by the Fellow from the Rubber Research Institute of Vietnam, and full experimental details can be found in Section 4 of this Report.

6.3 Results and discussion

6.3.1 Rolling resistance

The rolling resistance coefficients for each experimental tread type are shown in Table 6.1, together with the loss angles determined from dynamic mechanical thermal analysis (DMTA) measurements carried out by the Research Fellows from Sri Lanka and Thailand (Fifth Interim Report, Section 4).

It should be noted that in dealing with rolling resistance data, the *lower* the figure in comparison with the control, the better the performance of the tyre.

For the second stage radial compounds, although there are some discrepancies between the laboratory measurements and the data obtained using tyres, the advantage of the natural rubber and natural rubber/BR compounds is clear. The improvement in fuel economy will be substantial and will lead to considerable overall cost savings.

As noted above, these savings will be dependent on fuel cost, tyre mileage and tyre cost. In the Cote d'Ivoire, for example, where tyre costs are very high, the cost saving is equivalent to only a few per cent improvement in tyre mileage. However, for an articulated tractor unit operated in the UK, where tyres will last for up to 200 000km, the cost saving will be of the order of 10-15%. When the wear data for the tyres are taken into account, the potential cost savings for UK and areas with similar tyre wear severity conditions from the NR/BR/HS compound are very considerable.

The results for the second stage crossply tyres are not yet available, and the data for the first-stage crossply tyres (Table 6.1) are not consistent with the radial tyre results. The rolling resistance ratings for the natural rubber and NR/BR compounds are not as expected from the polymer content. An explanation may be the production conditions used for the first stage retreads. Because of the inability of the retread plant to vulcanize cross-ply retreads (see Third Interim Report), vulcanization was unavoidably carried out at a higher temperature than originally planned. This caused some loss of physical properties (reversion), particularly for the natural rubber and NR/BR compounds. Consequently the hardness and, more importantly for rolling resistance, resilience of the treads were reduced. The accompanying increase in hysteresis undoubtedly had an adverse effect on the rolling resistance of the tyres. The results in Table 6.1 for the cross-ply tyres may not be representative of the true compound effect on rolling resistance had the retreads been vulcanized at a lower, more usual temperature.

6.3.2 Wet traction

The wet traction data are shown in Table 6.2. Also included are the laboratory rankings determined by the British Pendulum Skid Tester (BPST) and DMTA measurements of the loss angle, tan δ.

In the trailer test there was no appreciable difference in wet skid performance between the SBR/BR control and the all-natural rubber, NR/BR or NR/BR/HS tread compounds at the three speeds used for the tests. This may be due to the testing use of relatively low speeds or an asphaltic concrete road surface which has little microtexture, making it difficult to detect small differences in performance. The NR/SBR shows a significant improvement of about 5% on the other compounds.

For the BPST and DMTA tests the differences between the compounds are quite significant. The BPST test was carried out on a concrete surface, which is noted for its microtexture and which is therefore more discriminating in detecting differences between rubber compounds. The rankings given by this test were

NR/SBR > SBR/BR, NR/BR/HS > NR/BR > NR.

Overall the NR/SBR compound gave an average of 5% improvement in wet skid performance.

The DMTA test is based purely on the dynamic properties of the compounds and does not take into consideration any effect of interaction between the tread and the road surface. The ranking of the compounds by this method was

NR/SBR > SBR/BR > NR/BR/HS > NR, NR/BR.

The high ranking of the compounds using SBR is not unexpected, since wet traction is one of the areas in which this polymer is particularly advantageous. However, the consistent higher ranking of the NR/SBR compound is of considerable interest, as is the performance of the high stearic acid formulation, which is either equal to or marginally inferior to the all-synthetic control.

6.4 Conclusions

On the basis of the data obtained for the second stage compounds, the expected improvement in fuel economy from the use of natural rubber-based truck tyre retread materials can be predicted with some confidence. It is also apparent that formulations can be devised which will not be significantly inferior to the all-synthetic compound in wet traction. The demonstration in in previous reports of the superior ice traction of these compounds helps to confirm that overall advantages should accrue from the use of natural rubber-based formulations for truck tyre retreads under most climatic conditions.

6.5 References

1. Cooper, L.C., Truck tires to meet present and future service requirements, *Rubber World*, 1985, **191**(6).
2. The Goodyear Tire and Rubber Co., Akron, Ohio The effects of Goodyear Unisteel radial ply tyres on fuel economy. Proceedings of SAE Conference on Tire Rolling Losses and Fuel Economy, Akron, Ohio USA, October 1977.
3. Schuring, D.J., and Futamara, S., Rolling loss of pneumatic highway tyres in the eighties. *Rubb. Chem. and Technol.*, 1990, **63**, 315.
4. Loh, P.C., See Toh, M.S., Othman, S., and Newell, R., MATRDS Convention, Kuala Lumpur, Malaysia, September 1987.

Table 6.1.
Rolling resistance data

Tread type	Rolling resistance coefficient x 10^3	Rolling resistance rating	DMTA tan δ	DMTA rating
Second stage radial				
SBR/BR control	8.27	100	0.185	100
NR/SBR	8.37	101.2	0.209	113
NR	7.62	92.1	0.184	99.5
NR/BR	7.79	94.2	0.172	93.0
NR/BR/HS	7.73	93.5	0.176	95.1
First stage crossply				
SBR/BR control	9.26	100	0.195	100
NR/SBR	9.77	105.5	0.209	107.2
NR	9.02	97.4	0.192	98.5
NR/BR	9.22	99.6	0.181	92.8
NR/BR/HS	9.25	99.9	0.181	92.8

Table 6.2.
Wet skid ratings of second-stage compounds

Tread type	Trailer test 25m/h	Trailer test 35m/h	Trailer test 45m/h	BPST	DMTA
SBR/BR control	100	100	100	100	100
NR/SBR	104	105	104	105	107
NR	99	100	99	93	90
NR/BR	101	101	100	96	88
NR/BR/HS	100	99	101	98	95

7 CONCLUDING WORKSHOP

7.1 Date and location

As agreed with UNIDO, the Concluding Workshop took place in Kuala Lumpur, Malaysia on 11th-13th February 1992. The meeting was held in the Conference Hall at the Headquarters of the Contractor, the Malaysian Rubber Research and Development Board.

7.2 Organization

The organization of the Concluding Workshop was undertaken by the Dry Rubber Technology Division of the Rubber Research Institute of Malaysia in consultation with the Team Leader. The arrangements included the participation of four speakers from industry, and visits to a major Malaysian retreading company and the Experimental Station and Technology Centre of the RRIM, as well as a Workshop Dinner.

Local publicity for the Workshop and arrangements at the venue were handled by the Publications, Library and Information Division of RRIM and the Publications, Publicity and Information Section of MRRDB.

7.3 Participants

A total of 68 participants attended the Workshop. They included representatives of UNIDO, UNDP, INRO, the German Federal Government and MRRDB, as well as representatives of IRRDB. All of the IRRDB Fellows attended and presented papers. Staff of the Contractor's headquarters and research units were present, together with four invited speakers from industry and over 30 representatives of the retreading and truck operating industries in Malaysia. A full list of participants will be included in the Proceedings of the Workshop.

7.4 Programme

The programme consisted of 24 papers, together with opening and closing remarks by Mr M. Youssef, Chief of the Petroleum Refineries and Petrochemical Industrial Unit of UNIDO, and by Datuk Ahmad Farouk bin Hj S.M. Ishak, Chairman of MRRDB and Controller of Rubber Research.

The papers were presented in five Sessions. The Opening Session under the Chairmanship of Dr P.W. Allen, Secretary of IRRDB, consisted of a Welcome Address by Mr Youssef and an Opening Address by Datuk Farouk. The Introductory Session began with a Keynote Address on the global scenario in truck tyre retreading, followed by papers on the choice of polymers for truck tyre retreading, the effect of carbon black on wear resistance, and reviews of the background to the Project and tyre testing techniques. The Technical Session consisted of presentations of the results obtained on wear resistance in the Project, together with papers on the influence of stearic acid on tyre wear, the result of traction and rolling resistance tests and a summary of the Complementary Research Projects carried out by the IRRDB Fellows.

The session on Technology Transfer began with a paper on truck tyre retreading techniques, followed by a review of the technology transfer aspects of the Project. Each of the IRRDB Fellows then presented a review of the status of truck tyre retreading in their own country. The session concluded with a Keynote Address on quality control in truck tyre retreading technology.

The UNIDO Consultant to the Project began the Concluding Session with a review of the Project and recommendations for future action. These recommendations were agreed by the Workshop. Mr Youssef and Datuk Farouk presented their closing remarks.

A copy of the programme follows this Section of the Report.

7.5 Proceedings

The papers presented at the Workshop will be published as Proceedings by the Malaysian Rubber Producers' Research Association in November 1992 and will be available at a moderate cost.

7.6 Conclusions

The results of the Project were presented and reviewed at a successful Concluding Workshop in Kuala Lumpur, Malaysia in February 1992. The recommendations for future work agreed at the Workshop are presented at the end of this report.

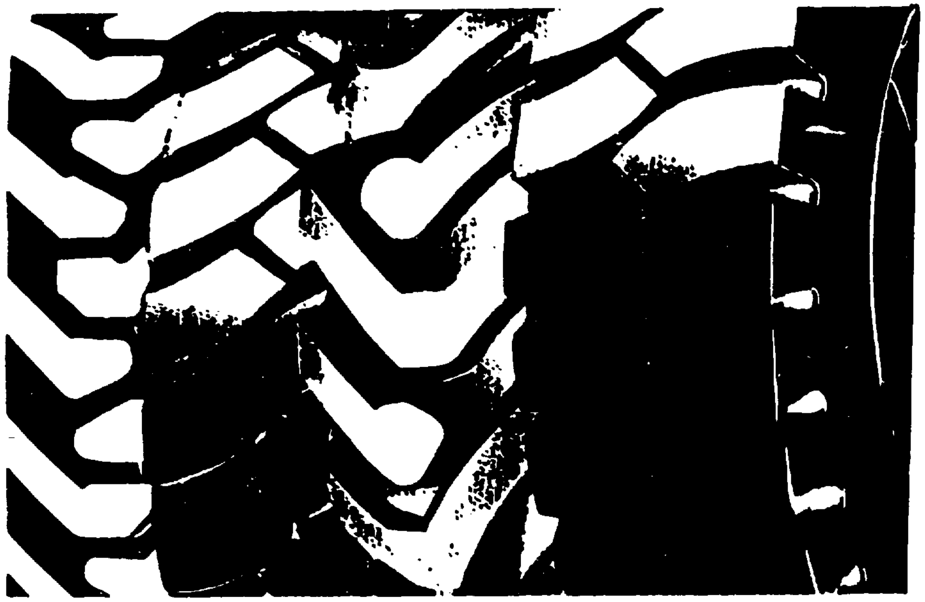
Programme

UNIDO WORKSHOP ON TRUCK TYRE RETREAD

11 – 13 February 1992

Conference Hall
1st Floor
Bangunan Getah Asli
Kuala Lumpur, Malaysia

Organised by
MALAYSIAN RUBBER RESEARCH AND DEVELOPMENT BOARD



PROGRAMME

TUESDAY 11 FEBRUARY 1992

0800 Registration

0845 Participants to be seated

OPENING SESSION

Chairman: Dr P.W. Allen
Secretary-General, IRRDB

0900 **Welcome Address**
M. Youssef
Senior Development Officer,
UNIDO

0910 **Opening Address**
Datuk Ahmad Farouk Haji S.M. Ishak,
Chairman, MRRDB and
Controller of Rubber Research

0930 REFRESHMENTS

INTRODUCTORY SESSION

Chairman: Dr D. Barnard
UNIDO Consultant

1000 **Keynote Address:**
The Global Scenario in
Truck Tyre Retreading
Tham Kim Choon, Bandag Inc.

1030	**Factors Affecting Polymer Choice in Truck Tyre Retreading** *Dr C.S.L. Baker, MRPRA*	
1100	**Invited Paper: Effects of Carbon Black on the Wear Resistance of Tread Compounds** *Ng Chiew Sum, Malaysian Carbon Sdn Bhd*	
1130	**The Truck Tyre Retread Materials Project: Background and Implementation** *M.E. Cain, MRPRA*	
1200	**Tyre Testing Techniques: Single or Multi-section Retreads** *Dr See Toh Mook Sang, RRIM*	
1230	LUNCH	

TECHNICAL SESSION

Chairman:	Dr Sekaran Nair Deputy Director (Research), RRIM	
1400	**Natural Rubber-based Retreading Materials for Crossply Tyres: Wear Results** *Loh Pang Chai, RRIM*	
1440	**Natural Rubber-based Retreading Materials for Radial Tyres: Wear Results** *R. Newell, MRPRA*	
1510	REFRESHMENTS	
1540	**Influence of Stearic Acid on Tyre Wear** *Dr I.R. Gelling, MRPRA*	
1605	**Traction and Rolling Resistance of Truck Tyre Retread Compounds** *Dr Sahrom Hasshim, RRIM*	
1635	**Complementary Research Projects: Summary** *R. Newell, MRPRA*	
1700	CLOSE	

WEDNESDAY 12 FEBRUARY 1992

TECHNOLOGY TRANSFER SESSION

Chairman:	Dr C.S.L. Baker Director, MRPRA	
0900	**Truck Tyre Retreading Techniques** *Sharif Othman, RRIM*	
0930	**Technology Transfer in the Truck Tyre Retread Project** *M.E. Cain, MRPRA*	
0945	**Status of Truck Tyre Retreading in Participating IRRDB Countries:**	
0945	China	*Wang Pingyue*
1000	Cote d'Ivoire	*S. Sylla*
1015	India	*Dr B. Kuriakose*
1030	REFRESHMENTS	

1100	Indonesia	*J.G. Abednego*
1115	Malaysia	*Loh Pang Chai*
1130	Nigeria	*I.K. Idehen*
1145	Sri Lanka	*Dr N.M.V. Kalyani*
1200	Thailand	*Mrs V. Kajornchaiyakul*
1215	Vietnam	*Tho Nguyen*
1230	LUNCH	

Chairman: Dr A. Kadir bin Mohamed
Assistant Director, Department of Chemistry & Technology, RRIM

1400 **Keynote Address:**
ISO 9000 in Truck Tyre Retreading
Lee Ng Chai, SIRIM

1430 **Invited Paper:**
Transfer of Retreading Technology
Sin Siew Weng, Kayel Retreads

1500 REFRESHMENTS

CONCLUDING SESSION

Chairman: Dr A. Aziz bin S.A. Kadir
Director, RRIM

1530 **Project Review: Conclusions and Recommendations for Future Action**
Dr D. Barnard
UNIDO Consultant

1615 **Closing Remarks**
M. Youssef
Senior Development Officer, UNIDO

1625 **Closing Address**
Datuk Ahmad Farouk bin Haji S.M. Ishak, Chairman, MRRDB and Controller of Rubber Research

1645 CLOSE

THURSDAY 13 FEBRUARY 1992

FIELD VISITS

0900 Autoways (Malaysia) Sdn Bhd - *For overseas participants only*

1100 RRIES, Sungai Buloh

1415 Technology Centre

8 FINAL PROJECT SUMMARY

8.1 Background

The Project was formulated in 1984 as a result of the severe threat to the market for natural rubber in truck tyre retreading posed by the increasing adoption of precured retreading technology using all-synthetic rubber tread materials. This was seen as a particular threat in natural rubber-producing countries where the impetus to implement the most up-to-date retreading technology might act to the detriment of natural rubber use in the local retreading industry. The consequence might then be the import of synthetic rubber or precured treads to replace natural rubber consumption.

The starting point of the Project was the work by the research and development laboratories of the Malaysian Rubber Research and Development Board showing that natural rubber-rich blends with synthetic rubber could be used successfully in the precured retreading process, and offered the possibility of equivalent wear performance coupled with lower rolling resistance for greater fuel economy. In particular, natural rubber-rich tread compounds with higher-than-normal levels of stearic acid had given indications of particularly good wear performance under some conditions.

8.2 Objectives and anticipated outputs

The objectives of the Project, as defined in the Project proposal incorporated into the Contract, were as follows.

To strengthen the position of natural rubber in the important market for truck tyre retread compositions. Specifically to assist the natural rubber producers to combat the threat of competition from all-synthetic 'precured treads' by:

(i) developing improved natural rubber-based formulations for truck tyre retreads, optimized for various conditions of service, and which are capable of matching the performance of all-synthetic formulations, especially in 'pre-cured' treads. At the same time, to establish suitable procedures for manufacturing retreads using the improved formulations,

(ii) promoting world-wide use of these formulations by

a) undertaking road testing of retreads made with the improved formulations under as wide a range of environmental conditions as is practicable,

b) diffusing to the natural rubber producing countries (and to developing countries generally) the technology of designing the improved formulations, and of making retreads from them, by providing training facilities at the Contractor's laboratories for staff from the member institutes of IRRDB.

By the completion of the Project the following outputs were anticipated:

a) optimization of formulations for truck tyre retreads enabling natural rubber to compete effectively with all-synthetic precured truck retreads,

b) commercially acceptable natural rubber-rich precured retread materials,

c) a report providing performance data based on well-planned and fully monitored road tests under a whole range of operating conditions,

d) identified potential markets for natural rubber-rich truck tyre retreads, including precured retreads,

e) acquisitions of new equipment and development of technical skills which will provide valuable strengthening of the laboratories of rubber research institutes in natural rubber producing countries,

f) the specific transfer of up-to-date technological know-how on truck tyre retreading of participating IRRDB Member Institutes,

g) transfer of expertise and experience in the arrangement, management and assessment of road fleet tyre trials to participating IRRDB Member Institutes,

h) strengthening of the co-operation between the natural rubber research institutes in a number of natural rubber producing countries; this co-operation to be effected through the IRRDB.

The results presented in the seven reports are assessed here first against these anticipated outputs, and then against the overall Project objectives.

8.3 Outputs achieved from the Project

8.3.1 Optimized natural rubber retread formulations

The wear trial results have shown very clearly, and not unexpectedly, that it is not possible to develop one single natural rubber-based truck tyre retread formulation giving the best performance under all conditions of service. The severity of service, indicated by the average tread lifetime and influenced mainly by road conditions, and the climatic conditions of the area are major factors in influencing the precise details of the formulation for optimum performance. Nevertheless, certain general guidelines have been clearly established for the composition of competitive natural rubber-based truck tyre retread materials. These general guidelines are as shown in Table 8.1. Where the tyre wear takes place under very low severity conditions, a compound with a high level of stearic acid will perform best, and under very high severity conditions an all-natural rubber compound will give the best performance. For intermediate wear severity conditions, the choice of a natural rubber-based compound will depend on the precise environmental conditions, the choice being between all-natural rubber and NR/SBR.

Further refinement of these formulations, particularly in terms of precise polymer blend ratio and oil level, should provide tread compositions capable of giving tread wear performance equal to that of commercial all-synthetic precured treads.

8.3.2 Commercially-accepted formulations

The results obtained in the Project have clearly shown that the natural rubber-based formulations used can be mixed, extruded, vulcanized and applied to buffed carcasses using commercially-acceptable procedures. When the benefits of lower rolling resistance, and thus fuel economy, are taken into account, natural rubber-based truck tyre retreading materials have been shown to be economically advantageous.

8.3.3 Performance data

The Project has successfully completed road trials using over 1800 retreads on more than 200 vehicles in six countries. The data accumulated have been presented at the Concluding Workshop, the Proceedings of which will be made available in November 1992. Together with Sections 5 and 6 of the present Report, this meets the requirements of the anticipated output.

8.3.4 Potential markets

The results obtained in the Project show that it is possible to formulate competitive natural rubber-based truck tyre retread formulations for a wide range of climatic conditions and all severities of wear. There is therefore no restriction on the market potential for those materials. It is likely that the advantages of fuel economy, and the benefits of improved tread life of high stearic acid formulations, will make them particularly advantageous in areas where the wear severity is very low, especially the United States of America. The verification of this potential market is one of the recommendations for future work.

8.3.5 Skills and equipment acquisition

The establishment of the modern precured truck tyre retreading plant at the Tun Abdul Razak Laboratory of the Malaysian Rubber Research and Development Board has provided facilities which can be made available for the training of staff from IRRDB Member Institutes. The operation of this plant in producing over 1800 retreaded tyres has enabled a team to be established with the necessary skills and expertise to provide a focus for the training of technicians from other rubber-producing countries.

8.3.6 Transfer of knowhow to IRRDB Member Institutes

The provision of nine IRRDB Training Fellowships, and the secondment of a staff member of the Beijing Research and Design Institute of the Rubber Industry to the Tun Abdul Razak Laboratory enabled up-to-date technological knowhow on truck tyre retreading to be effectively transferred to ten institutes, as anticipated.

8.3.7 Transfer of tyre trial management expertise

All of the staff of other institutes attached to the Tun Abdul Razak Laboratory during the Project were given training on the management of fleet trials. The successful completion of both first and second stage fleet trials in all six countries is evidence of the successful transfer of knowledge.

8.3.8 Co-operation between IRRDB Institutes

This output was ascribed to the IRRDB. However, it was apparent during the Project, when Fellows from various IRRDB member Institutes worked together at TARL, and when all the Fellows met at the Concluding Workshop that such contacts were both useful and productive. The individuals were able to appreciate more fully the roles played by the Institutes in their respective countries, and compare the initiatives being made in each case to encourage and promote the local rubber producing and manufacturing industries.

8.4 Realization of objectives

All of the objectives of the Project have been substantially achieved in that

* natural rubber based formulations have been developed for precured truck tyre retreads which can give wear results within a few per cent of a top quality all-synthetic tread, and offer potential advantages in fuel economy,
* general guidelines have been established for the optimization of natural rubber-based truck tyre retread formulations under a wide range of wear severity conditions,
* the suitability of the natural rubber-based retread formulations for commercial precured retreading operations has been established,
* a database of results from fleet trials in six countries has been established to provide information for the promotion of natural rubber-based truck tyre retread materials,
* modern state-of-the art technology on precured truck tyre retreading has been effectively transferred to ten institutes in nine developing countries,
* suitable avenues for future work have been identified.

8.5 Conclusion

The Project has been successfully completed, achieving the anticipated outputs and meeting the objectives laid out in the Project proposal.

Table 8.1.
Guideline retread formulations

Wear severity	Average tread life, km	Guideline formulation					
		NR	SBR	BR	Black	Oil	Stearic acid
Very high	<30,000	100	–	–	50	5	2
High	30–50,000	90	–	10	50	5	2
Moderate	50–75,000	80	–	20	50	5	2
Moderate	75–100,000	65	35	–	55	15	2
Low	100–150,000	65	35	–	55	15	2
Very Low	150–300,000	65	–	35	55	15	6

9 RECOMMENDATIONS FOR FUTURE WORK

9.1 Background

The major concern which led to the formulation of the Project in 1984 was the threat to the natural rubber market by the introduction of precured truck tyre retreads made entirely from synthetic rubber. Since then environmental concerns on the re-use and recycling of materials have served to emphasize the importance of the retreading operation in the conservation of materials. Although natural rubber itself is an environmentally friendly renewable resource, truck tyres necessarily contain high proportions of non-renewable resource material, including the steel in the beads, the steel or fabric reinforcement, and the oil-derived carbon black and synthetic rubber components. A retreaded truck tyre is estimated to require about one-third of the oil equivalent of a new tyre, and the recycling for one or even two retread lives is an important economic factor in the operation of commercial vehicle fleets. It is therefore likely that the truck tyre retread market will continue to grow in importance.

The advantages derived from the increased use of natural rubber in truck tyre retreading are not only beneficial to natural rubber producers. Apart from the environmental aspect, users of natural rubber-based truck tyre retreads should expect to obtain economic advantages from the improvements in fuel economy from using tread compounds with lower rolling resistance. This also has implications for environmental protection through the saving of fossil fuel.

9.2 Current status

As noted in Section 8, the present Project has firmly established the viability of increased use of natural rubber-based truck tyre retread materials under wide ranges of environmental and wear severity conditions. Significantly, a contribution from one of the world's leading precured retread manufacturers at the Concluding Workshop confirmed that in one rubber-producing country, Malaysia, commercial precured truck tyre retreads now contain a proportion of natural rubber.

The results of the Project have also clearly established that the use of natural rubber compounds containing higher than normal levels of stearic acid can give improved wear rates in the latter half of a tyre's life under conditions of medium to low severity of wear. The full benefits would be obtained under very low severity conditions and this has yet to be exploited.

A further outcome of the Project was the establishment of the wide variation in retreading practices in developing countries. They range from well-established retreading industries, *eg* in Malaysia, to poor quality retreading in Vietnam and the complete absence of retreading in Nigeria. In the last two countries it is considered economic to run new tyres to destruction, and considerable education programmes would be required to change this concept under their present economic conditions.

9.3 Future work

The growing importance of the truck tyre retreading market and its potential as an outlet for natural rubber from developing countries are both justifications for the continuation of work in this area. The major markets for truck tyre retreads are in the developed countries, particularly America and Europe. Efforts should therefore be made to promote the use of natural rubber-based truck tyre retreading materials in these countries. The most promising route for this promotion would be through the successful demonstration of fuel economies from the use of low rolling resistance natural rubber-based tread compounds. In these countries the use of high levels of stearic acid in the tread formulation would be particularly advantageous.

In those developing countries where retreading industries exist, the use of formulations particularly suited to the operating conditions encountered by vehicles should be promoted. On the basis of the results obtained in the Project, the use of natural rubber/synthetic rubber blends may give the best results in some countries. The retreading industries should also be encouraged to take advantage of lower production costs to enter overseas markets by exporting treads designed to give optimum performance in the country of destination.

In those developing countries where a retreading industry does not exist, steps should be taken to demonstrate the overall economic advantages of the retreading process.

It is likely that this work would be best accomplished through one or more internationally funded projects co-ordinated through the IRRDB.

9.4 Recommendations

The following recommendations were accepted by the Concluding Workshop.

Recommendation 1

A programme should be undertaken to demonstrate the advantages of natural rubber-based truck tyre retreads in the major world markets, especially North and South America and Europe, and in the potentially enormous market in China. Emphasis should be placed on clearly demonstrating fuel economy and the improved performance of high stearic acid formulations.

Recommendation 2

The results obtained in the Project should be promoted to local industries in the rubber-producing countries by the IRRDB Member Institutes. Emphasis should be given to the use of the most appropriate formulation in both precured and hot cap retreading.

Recommendation 3

Feasibility studies should be carried out on the establishment of production facilities for high quality precured retreads in the natural rubber-producing countries where they do not exist. They should be aimed at production for local and export markets.

Recommendation 4

Where retreading facilities are poor or non-existent the IRRDB should supply the necessary expertise available through its members to advise on the establishment of a pilot demonstration retreading factory.

Recommendation 5

Wherever possible these objectives should be achieved by projects co-ordinated through the IRRDB and funded internationally.

APPENDIX

UNIDO PROJECT FOR THE DEVELOPMENT OF NATURAL RUBBER-BASED TRUCK TYRE RETREADING MATERIALS

Report of training undergone at the

Tun Abdul Razak Laboratory

of the Malaysian Rubber Producers' Research Association

16th July to 12th October 1991

Submitted by

Mr Tho Nguyen

Rubber Research Institute of Vietnam

INTRODUCTION

As part of the UNIDO Project for the development of natural rubber- based truck tyre retreading materials, I was nominated by the Director of the Rubber Research Institute of Vietnam, a Member Institute of IRRDB, for a three-month Training Fellowship on various aspects of retreading technology at the Tun Abdul Razak Laboratory (TARL) from 16th July 1991 to 12th October 1991.

The training was valuable to my Institute as regards conducting studies of natural rubber in truck retreads. The three months of my training period was spent under the guidance of Mr R. Newell, Principal Scientist and Senior Technologist for the UNIDO Project.

My training report includes the following:

1. Familiarization with the facilities at MRPRA.
2. Full training in the operations of precured retreading and hot-cured retreading.
3. Familiarization with some tyre test methods.
4. Visits to tyre and retreading factories in the UK.
5. Complementary research project.
6. Conclusion.
7. References.

1 Familiarization with the facilities available at MRPRA

This included:

1.1 Familiarization with the safety code of MRPRA.
1.2 Familiarization with laboratory equipment and machinery.
1.3 Familiarization with the library facilities.

2 Full training in the operations of precured retreading and hot-cured retreading

Retreading can be carried out by either the hot-cured process or the precured process.

2.1 Precured retreading process

The precured retreading process involves principal steps as follows:

2.1.1 Selection and initial inspection of casing
2.1.2 Buffing and secondary inspection
2.1.3 Repairing and cementing
2.1.4 Building
2.1.5 Enveloping
2.1.6 Vulcanization
2.1.7 Final inspection.

The full details of each step have been described in the Second and Third Interim reports. A summary is given below.

2.1.1 Selection and initial inspection of casing

This step is very important because the success or failure of the precured retread process depends on the proper selection and initial inspection of the casing. Each tyre is thoroughly examined both internally and externally to ensure its suitability for retreading. This step should follow a strict standard, for example, British Standard BS AU144C. At this stage, the Collmann type 1004 Tyre Spreader Inspection Machine is used.

2.1.2 Buffing and secondary Inspection

The casing suitable for retreading is buffed to remove all unwanted old tread by mechanical abrasion with metal rasps on a buffing machine. The Collmann Type 0137 RM83 Buffing Machine is used at this stage. The buffed casing is again inspected.

2.1.3 Repairing and cementing

Any injuries are repaired according to the limits described in BS AU144C and the casing is cemented with a suitable rubber cement.

2.1.4 Building

After the satisfactory repair of the injuries and cementing, the tyre is then transferred to the building machine. The cushion gum and precured tread are then applied on to the surface of the casing. The Collmann Type 0034-1002 78NK Tyre Building Machine is used for this purpose.

2.1.5 Enveloping

This step requires different methods for steel radial and cross-ply casings. Two flexible envelopes are used for the steel radial-ply casing. The outer envelope is wrapped around the casing and the inner envelope is inserted into the casing. The cross-ply casing has also an outer envelope but inside the casing is fitted a curing bag and the whole assembly is mounted onto a rim. For both types of casing the Collmann Type 1033 Enveloper is used for the outer envelope whereas the insertion of the inner envelope or the curing bag/rim is done by hand.

2.1.6 Vulcanization

After enveloping, the tyre is placed into the Scholz 10-tyre Autoclave, the cure condition being three hours at 112°C. During the vulcanization of radial-ply retreads, the autoclave is pressurized to 6bar. A constant pressure difference of 1bar is maintained between the autoclave and the tyre inside the envelope. In cross-ply vulcanization, a constant pressure difference of 1bar is also maintained between the autoclave and the tyre inside the envelope. The internal inflation pressure of 8bar in the curing bag enables the shape of the tyre to be maintained.

2.1.7 Final inspection

The final inspection of the tyre is carried out to ensure the quality of retreads leaving TARL. The Collmann Type 1032 High Pressure inflation machine is used at this stage.

2.2 Hot-cured retreading process

The initial steps for the hot-cured retreading process are the same as for the precured retreading process described above. The main differences between these two processes are as follows:

At the building stage, uncured rubber compound is applied in the hot-cured process whereas tread already cured is applied in the precured process.

At the vulcanizing stage, the hot-cured process uses a curing mould/press with a designed matrix whereas the precured process uses an autoclave.

2.2.1 Building

At TARL, the AMF *Orbitread Series 200* machine is used to build rubber strips around the buffed casing. The AMF *Orbitread* machine is anelectro-mechanical device which automatically applies extruded rubber to the buffed casing. The extruded rubber in the form of a ribbon is wound around the casing in a continuous strip. The thickness of the tread is determined by the amount of the overlap from one adjacent strip to the next. The overlap is controlled by an electronic timing system which in turn, is programmed with a plastic programme card. Each programme card represents a different tread pattern as specified for each particular tyre and matrix in which it will be cured.

Rubber compound in strip form is fed into the extruder and forced through a strainer and die at the end of the extruder screw. The extruded ribbon of rubber is then passed under the "dancer arm roller", between the thickness monitoring rollers and pressed firmly and evenly onto the casing by a roller on the applicator head, as the casing revolves. The casing is moved about the applicator head in accordance with the predetermined programme which establishes the proper amount of overlap from one wrap of the ribbon to the next. When the tyre has been built the machine stops automatically.

2.2.2 Vulcanization

After building, the tyre is then transferred to a curing mould/press with a designated matrix. The heat source is from the matrix side only. The cure and time temperature depend on the curing characteristics of the tread rubber compound.

3 Familiarization with some tyre test methods

3.1 Accelerated wear testing

Road tests using the TARL trailer are carried out in order to assess the performance and structural integrity of retreads produced at TARL.

The tyre under test is inflated to the designated pressure and mounted onto the wheels of a Schallamach trailer. The load of the trailer can be adjusted depending on the load index of the test tyres. The slip angle of the tyres can be changed from 1.5° toe-in to 1.5° toe-out by a suitable mechanism fitted on the trailer through the driving vehicle. The trailer is pulled by the vehicle at an average speed of 50 miles/h for a distance of about 100 miles. The slip angle is changed from toe-in to toe-out every two miles.

There are two methods for measuring the wear rate:

Method 1: By weighing each deflated retread and the rim before and after the road test. The weight difference is the weight loss during that test. The wear rate is calculated as weight loss in grams/mile.

Method 2: By tread depth measurement. For measuring the tread depth, a digital tread depth gauge is used, measuring at 32 different points throughout the grooves of the tread surface, before and after the road test. The wear rate is calculated in millimetres tread depth loss/mile.

3.2 Skid resistance testing

Laboratory

Skid resistance testing can be carried out by using a portable skid resistance tester. The skid resistance tester is a pendulum device having a spring-loaded rubber slider. The slider is composed of a test specimen bonded to an aluminium backing plate, which is fixed to the bottom of the pendulum arm.

When the pendulum is released the rubber slider makes contact with an artificial road surface over a definite path length during its stroke. The energy loss of the pendulum arm, which balances the frictional work done by the slider, is a function of the skid resistance of the wet road surface and of the test specimen used.

Service

Wet traction testing can be carried out by using the Schallamach trailer. The tyres under test are fitted to the trailer with the wheels set at zero slip angle. A compressed air cylinder provides power to the brakes on the trailer: these are operated electrically and are independent of the brakes of the towing vehicle. The testing is carried out either at the Transport and Road Research Laboratory's (TRRL's) or Motor Industries Research Associations' (MIRA's) wet grip straight line braking facility where the surfaces are watered with a spray system. Skid path lengths are recorded, after applying the brakes on the trailer, using a distance counter located on the towing vehicle.

3.3 Endurance testing

The structural integrity of a retread is measured by conducting a constant speed/step load endurance test on the retread on a 1.70m. diameter drum of steel construction, according to British Standard BS AU144C. The equipment consists of an inflated tyre and wheel assembly, mounted on a free-running axle, with the tyre pressed against a power-driven rotating drum. Through the axle a force, related to the particular tyre's recommended load, is applied to the drum which is then rotated at a speed which is equivalent to the maximum recommended for that tyre for specified periods of time as follows:

7 hours at 66% of the rated load
16 hours at 84% of the rated load
24 hours at 101% of the rated load

At the end of the test if there is no damage to the tyre (according to BS AU144C) the tyre is considered to have passed the test. The test is not done on every tyre but is used as quality control.

3.4 Rolling resistance testing

Rolling resistance is measured from the torque input into a 1.70m. diameter steel drum. The torque is then electronically displayed on a panel. The display figure is three times the actual torque in rolling resistance measurement in Newtons. The test involves the following:

Prior testing: After mounting on the free-running axle, a truck tyre is given a four-hour break-in period at a drum speed of 20miles/h and at a load of 80% of the tyre's maximum rated load. The tyre is then conditioned for an 8-hour period in the test rig area.

Test 1: After the specified break-in and conditioning periods the inflation pressure must be rechecked and adjusted as necessary.

(a) The tyres are run at 50% of the maximum rated load at 50miles/h equivalent road speed (drum speed 20 miles/h for a specified period of time in order to reach equilibrium temperature. For truck tyres this is 90 minutes.

(b) After this equilibrium conditioning time, rolling resistance data are recorded from the torque display unit, 60 peaks and lows being recorded in an approximate ten minute period and the average rolling resistance under load recorded.

(c) The rolling resistance is then immediately recorded with the tyre in skim contact, zero load, zero slip conditions for 30 readings over an approximate 5 minute period. The function of this part of the test is to account for the frictional losses in the tyre axle/bearing system.

(d) The rolling resistance of the tyre in question is then calculated by subtracting the average skim reading from the average reading under 50% load and dividing by three.

Test 2: Immediately following test 1, the load is increased to 80% of the maximum rated load for the tyre. The speed is increased on the drum to 37 miles/h (road speed - 70 miles/h). The equilibrium conditioning times are repeated as in section (a) and the tests are repeated throughout as sections (b), (c) and in (d).

4 Visits to tyre and retreading factories in the UK

4.1 Vultra Rubber Co., Mold, N.Wales.

Vultra Rubber Co., Ltd., a member of the Retread Manufacturers' Association, is located in the North of England about 200 miles from TARL. Vultra is a small factory producing only precured treads.

This factory uses three machines for producing the precured treads:

(a) *Extruder*
The extruder has an output of 200kg/h. It is used to prepare the pre-formed slab of rubber compound for the tread moulding process.

(b) *Curing press*
The press, 11 metres in length, is four-day light, single cavity. The precured tread is formed in any designated tread pattern during curing in the press at 150°C. After curing the tread is de-flashed.

(c) *Tread buffer*
The precured tread then undergoes buffing. The buffing operation includes the following:

1. Buffing the under surface of the precured tread on a buffing machine which is fitted with carborundum paper.
2. Further buffing by hand if necessary.
3. Painting the buffed surface with rubber solution.

The finished precured tread is then protected by a polyethylene sheet and packed.

4.2 Lynx Factory, Grantham, Lincs.

Lynx Factory, a small factory, is located about 100 miles from TARL. This factory produces only 200 retreaded tyres (light truck) per week, with three workers. It uses the rimless vulcanization system, using precured treads and machines which are supplied by RTS.

The autoclave used in this factory has a capacity for curing about 6-8 tyres depending on the tyre size.

At the time of the visit, I buffed 24 car tyres under the supervision of two members of the Project Team, Mr I Wallace and Mr L Goodman.

4.3 Watts Industrial Tyre Co., Lydney, Gloucs.

Watts Industrial Tyre Co. is located in the west of England, about 150 miles from TARL. This factory has two premises, one of which is for mixing compounds and the other for solid tyre production.

4.3.1 Compound Production

The factory uses a significant amount of natural rubber in compound formulations, most of it being purchased from Nigeria. It has three types of machinery for compound production.

F9 (Farrel Bridge) Banbury mixer with capacity 140kg

two mills

VMI for producing slabs of rubber or strips for the *Orbitread* machine.

The factory can produce 200 tonnes of rubber compound/week.

4.3.2 Solid tyre production

The factory also produces many kinds of solid tyres with a production of 4000 solid tyres/week. Forty-five compression presses are used for moulding the solid tyres. The main compound used for the production of solid tyres is scrap rubber (textiles, *etc*) from different sources. However, fresh rubber compounds are used for the tread section. About 50% of the solid tyres are exported to Europe and the USA, the remainder are used for local needs, with around 30% for the OE market and 20% for the replacement market.

4.4 Premium Retreads, Stafford, Staffs.

Premium Retreads produces both hot-cure and precured retread truck tyres. It is a RTS Marangoni franchisee. For conventional retreading building is carried out by an *Orbitread* machine. They have three presses (Marangoni) and produce some thirty hot-cure retreads per week. *Orbitread* strip is supplied by British Vita.

They also produce about 50 precured retreads per week. The building machine is somewhat old and also doubles as a buffing machine. They have two four-chamber autoclaves and one two-chamber. Curing is for two hours at 130°C.

4.5 Smallwood Retreads (Bandag), Newcastle-under-Lyme, Staffs.

Smallwood was until recently an Oliver franchisee. Due to a certain amount of disaffection with the parent body the proprietor approached Bandag for assistance. Smallwood is now a Bandag franchisee. All the machines (new) have recently been installed by Bandag engineers, who are currently training the staff in the use of the machines. All the methods used during the building process are not significantly different from other precured methods. The curing of the retreads is carried out for three hours at 99°C in a 22-chamber autoclave. The method of curing is the ARC Bandag method. It is essentially a pressure differential control system similar to the double envelope system except that only one outer envelope is employed. This is sealed by use of two separate bead rims. Autoclave pressure is allowed to build up to 3bar after which the DPC commences. Maximum pressure in the autoclave is 6bar with 5bar in the outer envelope.

The Company hopes to produce 200 retreads per week (COC and stock casing) with a workforce of ten.

4.6 Vacu-lug Traction Tyres Co., Grantham, Lincs.

Vacu-lug Traction Tyres Ltd, the biggest tyre retreader in the UK, is located about 120 miles from TARL. This factory produces both hot-cure and precured retread truck tyres. It produces 2500 hot-cure retreads and 500 precured retreads per week. Total staff is 220.

4.6.1 Hot-cured retread production

The buffing machine for truck tyres has four buffing heads to buff a tyre from two sides at the same time, crown and sidewall respectively. The first part of the old tread layer is "peeled" off to save buffing time.

Truck retreads. Two *Orbitread* extruders are used to build the rubber strips around the buffed casing. The retreaded casings are then cured in steam-heated moulds with designated matrices.

Earthmover retreads. A two-ram extruder (vertical ram and horizontal extruder head) is used to extrude the wide, thick, slab rubber. The slab rubber is then built onto the cemented earthmover casing's surface. The grooves on the tread pattern are cut out by using a big hot-grooving knife. The retreaded earthmover tyres are then cured in big steam-heated autoclaves. During curing, the tyres are hung on rotating spindles to eliminate local bead distortion.

Tractor retreads. A Barwell extruder with a specially designed extruder head is used to extrude the head for tractor casings. The retreaded tractor tyres are cured in steam-heated moulds.

4.6.2 Precured retread production

The curing of the retreads is carried out for 2 hours and 25 minutes at 125°C in an autoclave. The method of curing uses only an outer envelope and is sealed by use of two separate bead rims. Maximum pressure in the autoclave is 6bar with 5bar in the outer envelope.

5 Complementary research project – Wet traction testing of truck tyre retread compounds in service.

The details of the experiments conducted, service testing, results and discussions are given earlier in this Report.

6 Conclusion

During the training at TARL, I gained a lot of knowledge regarding precured and hot-cured retreading as well as tyre test methods. It has been valuable for our Institute and will enable us not only to optimise the use of natural rubber in local retreading but also to improve local retreading practices.

7 References

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