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ROADEX III
NORTHERN PERIPHERY

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Tyre Pressure Control on Timber Haulage Vehicles

Some observations on a trial in Highland, Scotland

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February 2008

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PREFACE

This is a final report from Task B2 of the ROADEX III project, a technical trans-national cooperation project between The Highland Council, Forestry Commission Scotland and Comhairle Nan Eilean Siar from Scotland; The Northern Region of The Norwegian Public Roads Administration; The Northern Region of The Swedish Road Administration and the Swedish Forest Agency; The Savo-Karjala Region of The Finnish Road Administration; the Icelandic Road Administration; and the Municipality of Sisimiut from Greenland. The lead partner in the project is The Northern Region of The Swedish Road Administration and project consultant is Roadscanners Oy from Finland.

This report summarizes a trial of a “Tyre Pressure Control System” (TPCS) on the A987 and B871 public roads in the Highland area of Scotland and includes inputs from other field tests in Scotland, Sweden and Canada. The work has been carried out in close collaboration with Task B2 “Developing and applying a basic understanding of low volume pavement behaviour”, the results of which are presented in a separate report. The report was prepared by Ron Munro of Munroconsult Ltd, working under sub-contract to Roadscanners Oy, on behalf of the Task B2 project team comprising Frank MacCulloch of Forestry Commission Scotland, Andrew Dawson of the Nottingham Centre for Pavement Engineering at the University of Nottingham (UK), Pauli Kolisoja and Nuutti Vuorimies of the Tampere University of Technology, Finland. In addition contributions have also been given by Timo Saarenketo of Roadscanners Oy, Svante Johansson of Roadscanners Sweden AB and Daniel Lamb of Michelin UK. Vehicle trials described in the report were carried out on the A897 and B971 public roads in Sutherland, Scotland. Additional test results from Sweden were provided by the Swedish Forest Agency (Skogsstyrelsen) and the Swedish Road Administration (Vägverket). The information on trials in Canada was provided by FERIC and Tire Pressure Control International Limited. Mika Pyhähuhta of Laboratorio Uleåborg designed the graphic layout.

The authors would like to express their gratitude to Mike Howden of the UK Vehicle and Operators Services Agency (VOSA), Sandy Hogg, Jonathan Ritchie and Aaron Skene of James Jones & Sons Ltd, Gordon Mackenzie and Peter Dowson of GA Mackenzie (Kinbrace), Garry Smith and Richard Blain of The Highland Council, Allan Bradley Glen Légère of the Forest Engineering Research Institute of Canada (FERIC), and Brian Spreen of Tire Pressure Control International Limited of Edmonton, Alberta. Their assistance is greatly appreciated.

Finally the authors would like to thank the ROADEX III Project Partners and the Project Steering Committee for their guidance and encouragement in this work.

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CONTENTS

Abstract

The European Union ROADEX Project 1998 – 2007 is a trans-national roads co-operation aimed at developing ways for interactive and innovative management of low traffic volume roads throughout the cold climate regions of the Northern Periphery Area of Europe. Its goals have been to facilitate co-operation and research into the common problems of the Northern Periphery. This report gives a summary of the results of a trial of a system of tyre pressure control fitted to a timber haulage vehicle at Kinbrace in northern Scotland from October 2006 to November 2007.

Variable tyre pressure control systems, or ‘tyre pressure control systems, have been gaining acceptance internationally as useful mechanisms for optimising load, speed and air pressure in tyres, especially on those vehicles involved in heavy haulage operations that travel over a range of road types in their daily journeys, such as in timber transport. Having the correct pressure in tyres, it is argued, can improve the management of the tyres on a vehicle, increase the traction through the tyre and reduce the consequent damage to roads and at present there are 2500 vehicles equipped with TPCS in North America, and this number is growing as operators see the benefits of the system.

The 2006-2007 trials of tyre pressure control at Kinbrace by Forestry Commission Scotland (FCS) were the first in the UK and the information obtained during the trials raised a number of considerations for the future of hauling in the Scottish timber harvesting industry over the coming years. This paper is a preliminary report on the FCS trials and touches on:

- A general introduction to tyre pressure control systems
- The background to the commissioning of the Highland trial
- The conduct and results of the trial

It concludes with a discussion on the performance obtained from the perspective of the vehicle owner, operator and driver rather than that of the road owner with some possible ways forward.

Chapter 1. INTRODUCTION

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between roads organisations across northern Europe that aims to share roads related information and research between the partners. The Project was started in 1998 as a 3 year pilot co-operation between the roads districts of Finnish Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005. and a third, ROADEX III, from 2006 to 2007.

The partners in ROADEX III "The Implementation Project" comprised public road administrations and forestry organizations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland & Comhairle Nan Eilean Siar from Scotland, The Northern Region of The Norwegian Public Roads Administration, The Northern Region of The Swedish Road Administration and the Swediish Forest Agency, The Savo-Karjala Region of The Finnish Road Administration, the Icelandic Road Administration and the Municipality of Sisimiut from Greenland.

Figure 1.1 Northern Periphery Area & ROADEX III partners

A priority of this Project was to take the collected ROADEX knowledge out into the Partner areas and deliver it first hand to practising engineers and technicians. This was done in a series of 14 seminars across the Partner areas to a total audience of 800. Reports were translated into the 6 partner languages of Danish, Icelandic, Finnish, Greenlandic, Norwegian and Swedish as well as English. ROADEX research continued through 5 projects: measures to improve drainage performance, pavement deformation mitigation measures, health issues of poorly maintained roads, road condition management policies, and a case study of the application of ROADEX methodologies to roads in Greenland. This report is a sub-report of Task B2 "Pavement Deformation" and has been done in close collaboration with the Task B2 sub-task "Developing and applying a basic understanding of low volume pavement behaviour" the results of which are presented in a separate report. All of the reports are available on the ROADEX website at www.roadex.org.

1.2 BACKGROUND

Variable tyre pressure control systems, or ‘tyre pressure control systems, have been gaining acceptance internationally as useful mechanisms for optimising load, speed and air pressure in tyres, especially on those vehicles involved in heavy haulage operations that travel over a range of road types in their daily journeys, such as in timber transport.

Having the correct pressure in tyres, it is argued, can improve the management of the tyres on a vehicle, increase the traction through the tyre and reduce the consequent damage to roads and at present there are 2500 vehicles equipped with TPCS in North America, and this number is growing as operators see the benefits of the system.

With such apparent benefits being demonstrated in North America it is surprising that the system was not better known in the ROADEX area of northern Europe at the commencement of the project. Forestry Commission Scotland (FCS), a full partner in the ROADEX III Project, was keen to remedy this situation in Scotland and arranged to introduce TPCS into the Highland area by means of an operational test on a typical Scottish rural timber haulage route involving forest, rural and main roads.

The 2006-2007 trials of tyre pressure control at Kinbrace by FCS were the first of their kind in the UK and the information obtained during the trials raised a number of considerations that will doubtless stimulate close discussion within the timber harvesting industry over the coming years. This report is a preliminary report on the FCS trials and aims to set out:

- A general introduction to tyre pressure control systems
- The background to the commissioning of the Highland trial
- The conduct and results of the trial

and concludes with a discussion on the performance obtained from the perspective of the vehicle owner, operator and driver rather than that of the road owner with some possible ways forward.

Note: To avoid confusion with those simple tyre maintenance systems that only monitor and maintain tyre pressures, this report will use the generic term of Tyre Pressure Control System, or TPCS, for the tyre pressure control system that both inflates and deflates tyres as used in the Highland trial.

1.3 INTRODUCTION

It is fact of life that many rural roads in the Northern Periphery are subject to weight restriction periods during the winter months when pavement layers and subgrades are at their weakest due to daily freeze-thaw cycles. Such restrictions on heavy haulage routes cause serious disruptions to local communities and businesses, and to the forest industry in particular, who depend on a continuous supply of fresh raw materials to remain efficient and competitive.

Unfortunately the funding for these minor rural roads is not sufficient to permit the widespread road strengthening measures to be carried out to meet the needs of heavy haulage and it is therefore urgent that alternative ways are pursued to address the problem.

One way, being used in Canada, USA and Sweden, is to use 'road friendly' vehicles with variable tyre pressures that reduce stresses on weak roads. By reducing air pressure in tyres the loaded area on the road surface can be increased and the load distribution within the road structure improved. This technology, it is argued, reduces the deterioration of the road and minimises the need for temporary load restrictions minimised.

This report documents the FCS trial of a tyre pressure control system fitted to a 44 tonne gross train weight (GTW) timber haulage vehicle on a timber haulage route in Scotland.

1.4 BACKGROUND TO THE TRIALS

The FCS trial at Kinbrace is part of a larger, longer term collaboration between the Highland Council and Forestry Commission Scotland to facilitate the extraction of timber from the forest areas of Naver and Rimsdale in central Sutherland. These forests have a combined area of approximately 3,000 hectares and are essentially landlocked for timber harvesting apart from the local single track public road network. They were planted at a time when there was little thought given to the problems that the timber extraction might eventually cause and currently the only available route from the forests along a public road is via the 55km, 2.7m wide, single track route from Syre to Helmsdale that has been assessed as being too weak to take the timber traffic. The cost of improving this road to a standard suitable for heavy haulage traffic has been estimated to be over £10 million and this level of funding is not available to the roads authority.

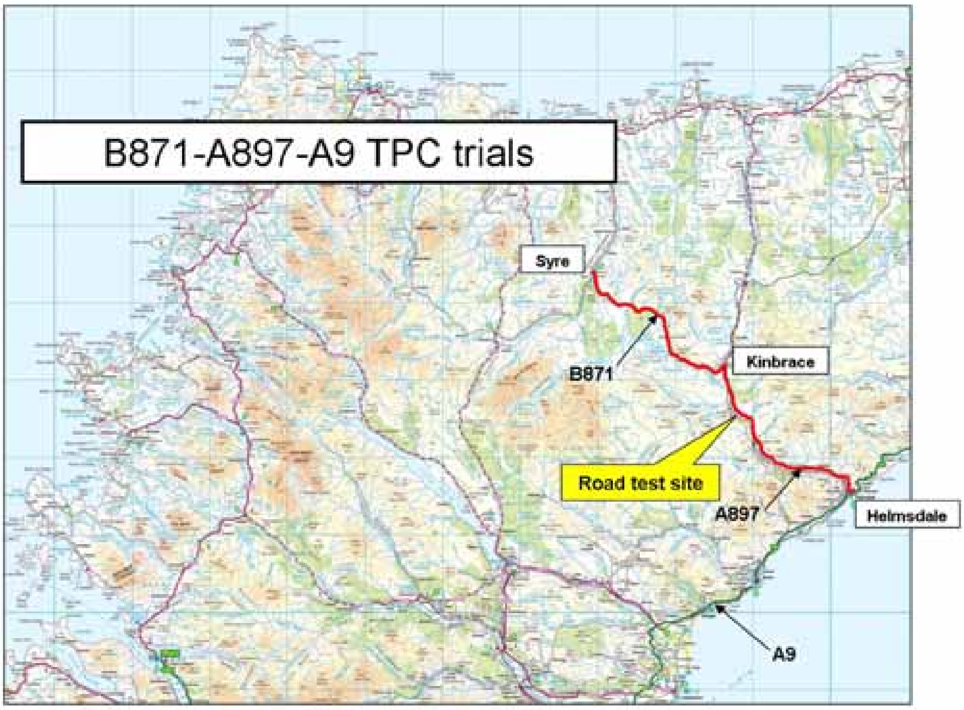


Figure 1.2 Location of the B871 – A897 timber haulage route

In an innovative co-operation that broke new ground in partnership with the forest industry at the time, The Highland Council and Forestry Commission Scotland entered into a formal agreement in 2001 to jointly use the single track road as a test bed to trial low cost remedial measures from the forest industry on the public road network. Prior to this the only option available to the roads authority would have been to impose weight limits on the public road to preserve the existing road structure but this action was recognised as having the potential to damage the interests of local communities and businesses served by the road. The co-operation recognised the joint vested interests of both Partners to ensure that:

a) the forests could be managed and harvested as programmed;
b) local communities could have uninterrupted access to the public road; and
c) that local employment could be sustained in the area.

The agreement was set up for an initial 25 year period covering the 30km of single track B871 road from Syre to Kinbrace and was subsequently informally extended to include the additional 25km of A897 from Kinbrace to its junction with the A9 Trunk Road at Helmsdale to permit testing of vehicles equipped with TPCS.

An advantage of testing these particular sections of roads was that they were relatively lightly trafficked routes, apart from the proposed timber traffic and it was expected that the increased loading from the trials would be able to be quantified. In 1998 the AADT of A897 road was 140 vehicles per day, with 18% HGV,

The trials were jointly undertaken by The Highland Council, Forestry Commission Scotland and the ROADEX III Project and benefited from having direct access to the international experience of ROADEX in which both the Council and FCS participate. Through this extended co-operation a range of innovative techniques from the Partner organisations were also available for trial on the road.

1.5 TIMBER HAULAGE V IMPACT ON ROADS

The forest industry and its associated infrastructure play an important part in the economy of the Highland area and harvesting activities are planned to rise by 50% from 2007 to 2016.

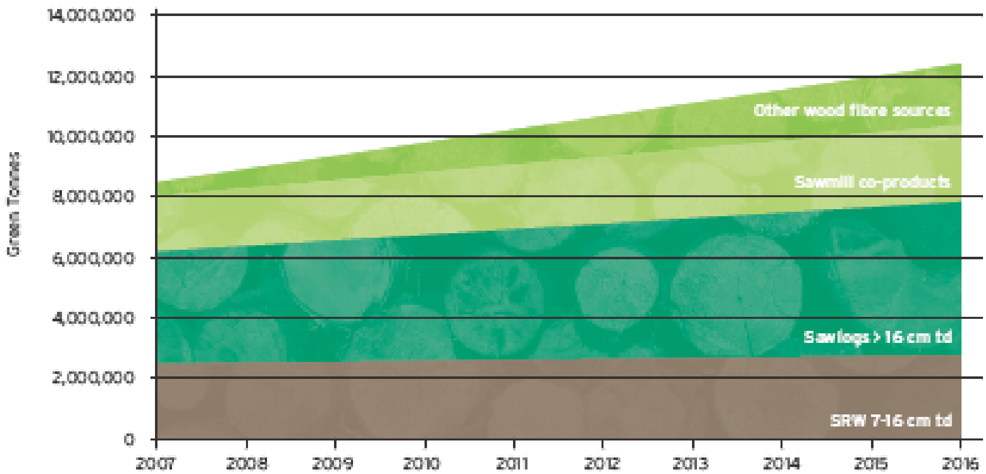


Figure 1.3 "Forecast wood fibre availability & demand in Scotland & Northern England to 2016", Executive Summary prepared for the Wood Fibre Processing & Supply Industry, Nov 2006

The Highland Council and Forestry Commission Scotland recognise the strategic benefit of the forest industry to the Highland area and have agreed a harvesting and transportation protocol that will permit harvesting to be carried out whilst minimising the damage to the rural road networks.

At the heart of this protocol lies the joint "agreed routes strategy" which sets out those routes that have been deemed suitable for timber transport. "Agreed routes" maps have been prepared by local Regional Timber Transport Groups, using information from timber transport surveys, and these have been circulated for wider comment before being finalised. The route classification for the maps is as follows:

Agreed Routes - Routes which can be used for timber haulage without restriction as regulated by the Road Traffic Act 1988.

Consultation Routes - Routes which are recognised as being key to timber extraction but are not up to the standards of the Agreed Routes. Consultation with the Local Authority is required before the route can be used, and it may be necessary to agree restrictions on timing, allowable tonnage, etc.

Excluded Routes - Routes which should not be used for timber transport in their present condition. These routes are either formally restricted, or are close to being formally restricted, to protect the network from damaging loads. Consultation with the Local Authority is required to explore alternatives.

The B871 and A897 public roads of the TPCS trials were designated as Consultation Routes in the "Agreed Routes Strategy". An abstraction of the Agreed Routes map for Sutherland is shown in Figure 1.3 below.

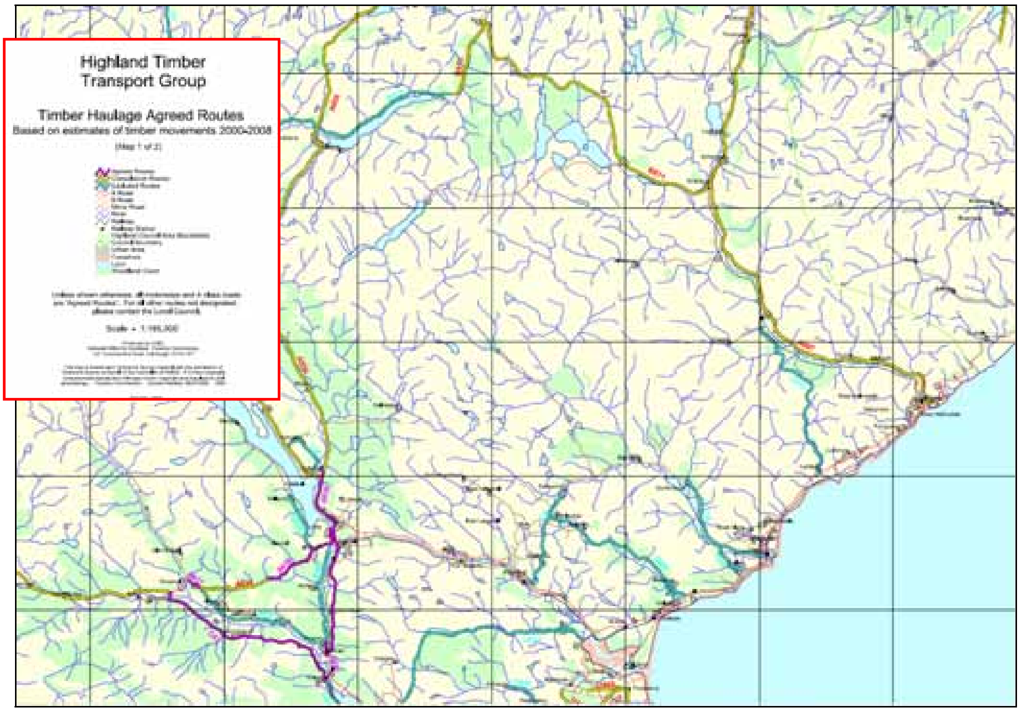


Figure 1.4 Abstract from the Highland Timber Haulage "Agreed Routes" Map for East Sutherland

1.6 B871 - A897 SEASONAL WEIGHT RESTRICTION

As mentioned above, the B871-A897 public road was classified as a "Consultation Route" at the time of the TPCS trial and as part of the management of this route it had been agreed that timber traffic would be restricted using the route during the perceived weakest winter months in an effort to safeguard the road from damage. Up until 2001, this restriction was in place from November to March inclusive and was based on historic local experience of using the route. This restriction was considered to be the shortest period possible to preserve the route. The restriction had however a significant effect on the harvesting plans for forest blocks at Syre and for the supply of raw timber to the production units across the extended Highland area.

Fortunately in recent years, 2002-2005, the B871 section of the route had been used a test road for research in the ROADEX II Project and had been the subject of a number of condition and structural surveys that gave a sound understanding of the varying strength of the road over the course of the year (Saarenketo et al, 2001 and 2004). As a result of these surveys, and subsequent analyses undertaken for the ROADEX II Project, the restriction period for timber transport was reduced from the historic 20 weeks period to the 10 week period from mid December to mid February for winter 2004-2005 as determined from live data from the ROADEX "Percostation" located at Garvault shown in Figure 1.4 below. This 10 week gain in the historic transportation window, from the former 20 week restriction to the 10 week restriction, permitted a longer harvesting and hauling season and benefited local employment.

Strategic pressure for increased timber volumes from the area continued however and as a result further solutions were actively pursued to identify possible "road friendly" options that could permit the transportation of timber during the remaining weak period. This report is an output from one of these trials.

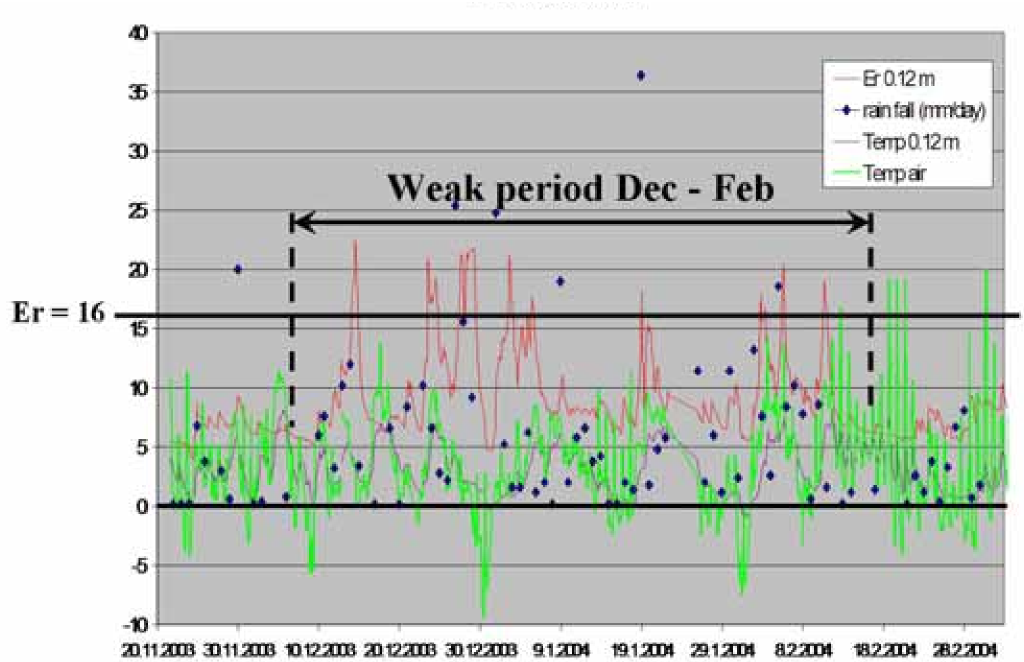


Figure 1.5 Output screen from a Percostation on the B871 showing basecourse dielectric value & temperature, air temperature and daily rainfall. The weak period for timber traffic is based on a basecourse dielectric value of 16.

Chapter 2. TYRE PRESSURE CONTROL

2.0 INTRODUCTION

“Tyre Pressure Control” (TPC), sometimes generically called “Central Tyre Inflation” (CTI), is the descriptive terminology for an onboard automated system that permits the driver of a vehicle to adjust the pressure of the tyres on the vehicle whilst the vehicle is in motion. A number of TPCS are available worldwide of which “Bigfoot”, “Air CTI”, “TIREBOSS”, “Syegon” and “ROADRANGER SPICER” are common. The system used in the trial in Highland was the “TIREBOSS” TPCS system as manufactured by Tire Pressure Control International Ltd of Edmonton, Canada.

In a perfect scenario a tyre on a vehicle is designed to have uniform contact with the road surface across its width and spread the load it carries across the full width of tread. Where this happens, the tyre should experience even and optimal wear across its tread and hence produce maximum tyre life. Tyres that are over-inflated or under-inflated cannot achieve this desirable uniform contact of the tread with the road surface and as a consequence generally experience uneven wear and reduced tyre life, as shown in Figure 2.1 below.

Figure 2.1 Diagrams showing effects of over and under-inflated tyres (courtesy of Michelin UK)

2.1 TYRE MANAGEMENT – WHY IS IT NEEDED?

In an effort to achieve the desired effect of good tyre/road contact and even tyre wear, commercial tyre manufacturers suggest tyre inflation pressures for their tyres that take into account the load carried by the tyre, the speed of the vehicle and the expected operational usage. These suggested inflation pressures are the tyre manufacturer’s best estimate for the optimal tyre pressure to suit the range of duties expected of the tyre and are specific to each vehicle’s operation and load carried. It is not therefore possible, or desirable, for the tyre manufacturer to give a standard tyre pressure setting for each type of tyre. The inflation pressure will depend on the particular circumstances of each use.

Good tyre management recommends that tyres are checked daily as part of drivers’ daily checks and that tyre inflation pressures are checked weekly to identify any deviations from manufacturer’s suggestions and thereby maximize tyre life. This recommended practice is not however always translated into action on all vehicles. Few small companies have either the time, or the capacity, to establish regular tyre inspection regimes other than the normal vehicle servicing intervals within their organisations and most rely on the “Driver’s daily checks”, or monthly servicing checks, to identify tyre pressure variances.

Informal research for this project in Scotland has revealed, where a weekly system of tyre pressures has been implemented, it has shown real improvements in tyre management but has to be scheduled for a period that most trucks are available. If this can be done tyre checks can take approximately 6 minutes per vehicle for a 20 tyre combination, including recording results. Valve extensions will have to be fitted to twin tyre assemblies to permit this check however.

A study in 2002 in North America by the Technology & Maintenance Council of the American Trucking Associations surveyed over 6000 heavy vehicles, involving 35,000 tyres, and reported the following:

- approximately 19% of tyres in fleets of less than 50 trucks were under-inflated by 20 psi (138 kPa) or more;
- 1 out of 5 trucks inspected had at least one tyre that was under-inflated by 20 psi (138 kPa) or more;
- 3% of all trucks inspected had 4 tyres or more under-inflated by 20 psi (138 kPa) or more
- Twin tyres were a particular problem: 20% of twin tyres on drive axles varied by more than 20 psi (138 kPa); 25% of twin tyres on trailer axles varied by more than 20 psi (138 kPa).

These north American findings raise concerns but they are not unique to north America. Similar variances have been confirmed in a local, random vehicle check in the north of Scotland carried out by James Jones & Sons Ltd on their timber haulage fleet. Their finding were that tyre pressures could vary by +/- 10 psi (69 kPa) across axles and by +/-20 psi (138 kPa) across the fleet.

Michelin reports that “Under or over-inflation of tyres can be very costly and even dangerous. Mileage performance, comfort, transmission of traction and braking, in fact all elements of tyre performance, can be affected by their inflation pressure. Under-inflation means extra flexing to the casing. This causes the tyre to heat up, increases rolling resistance and increases wear. In extreme cases, under-inflation can result in tyre failure. Over-inflation can also reduce mileage potential. It reduces grip and increases irregular wear, in particular on drive axles”. (Michelin website).

Discussions with Michelin UK during the present project revealed their experiences in monitoring the performance of tyres of heavy haulage vehicles. Their experience is that the following losses can be incurred with incorrect tyre pressures.

Table 2.1 Potential reductions in tyre life (from Michelin UK)

PRESSURE VARIANCE	Potential reduction in tyre life
>15% over-inflated	20%
11-15% over-inflated	13%
6-10% over-inflated	5%

Within 5% of recommendation	0%
6-10% under-inflated	10%
11-15% under-inflated	19%
>15% under-inflated	25%

Using these percentages it is possible to approximately estimate the costs of incorrect tyre inflation to a vehicle or fleet. For example, if the tyres on a twin tyred timber haulage vehicle with 22 tyres were 10% under-inflated, and required 2 tyre changes per year, this would cost the operator approximately 2 x 22 x 400€ x 10% = 1760 €/vehicle/year, ie a substantial cost.

The manufacturer's suggested tyre pressure is however a 'best fit' suggestion to suit the specific haulage operation under review and as such it tries to reflect the likely demands on the particular tyre such as loads carried, unloaded times, operational speeds, types of roads travelled, etc. A long distance inter-city heavy haulage operation, loaded in both directions, will therefore have different suggested pressures to those of a timber transport vehicle that travels on a mixture of forest and public roads and is only loaded in one direction. It is therefore important that tyre manufacturers are consulted in the use of their tyres ahead of use, and that once pressures have been suggested for specific operations, they are adhered to as closely as possible to maximise the potential performance of the tyre.

Using TPCS it is possible to take the next step in best practice tyre management and vary the inflation pressures of tyres under control to suit the actual load in the tyre, the speed of the vehicle, the bearing capacity of the road, the road surface properties, etc. The Highland trail was commissioned to assess the effectiveness of this practice when applied to a timber haulage vehicle.

2.2 TYRE PRESSURE CONTROL – WHAT IS IT?

In its simplest form TPCS takes compressed air from the vehicle's onboard compressor and routes it through hoses, under control, to inflate the vehicle's tyres. Similarly, when pressures are required to be lowered rather than raised, valves located on the wheels are opened, again under control, to permit air to be released to deflate the tyre.

An interesting feature with radial tyres, the type of tyres normally used in heavy haulage operations, is that the reinforcement layers in the tyre limit the tyre contact width on the road. The net result of this is that when lowering (or raising) the pressure in a radial tyre, the contact area on the road increases (or reduces) and this has the effect of changing the tyre's contact length, or "footprint", on the road surface. The difference the tyre footprint created by a high pressure tyre to that of a lower pressure tyre can be seen in Figure 2.2 below.

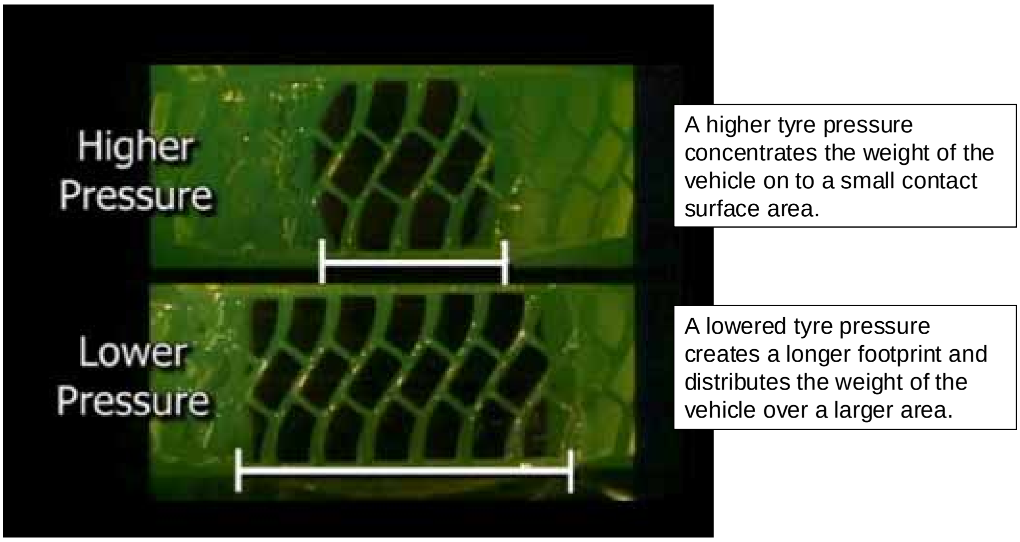


Figure 2.2 Lengthening the footprint of a radial tyre by lowering its inflation pressure (TPC International)

This difference in the footprint created is an important feature for a heavy haulage vehicle as a longer tyre footprint, and increased number of tread blocks in contact with the road, can distribute the weight of the truck over a larger surface area. This, and the increased number of edges from the tread blocks in contact with the road, can offer increased traction and mobility for the vehicle.

A further noteworthy feature of variable tyre pressure is that in twin tyre systems, the tyre arrangement generally favoured by road administrations, is that the tyre pressures are equalised across the tyre pairs giving rise to a better distribution of load between the tyres and equal contact patterns on the road, as shown in Figure 2.3 below.

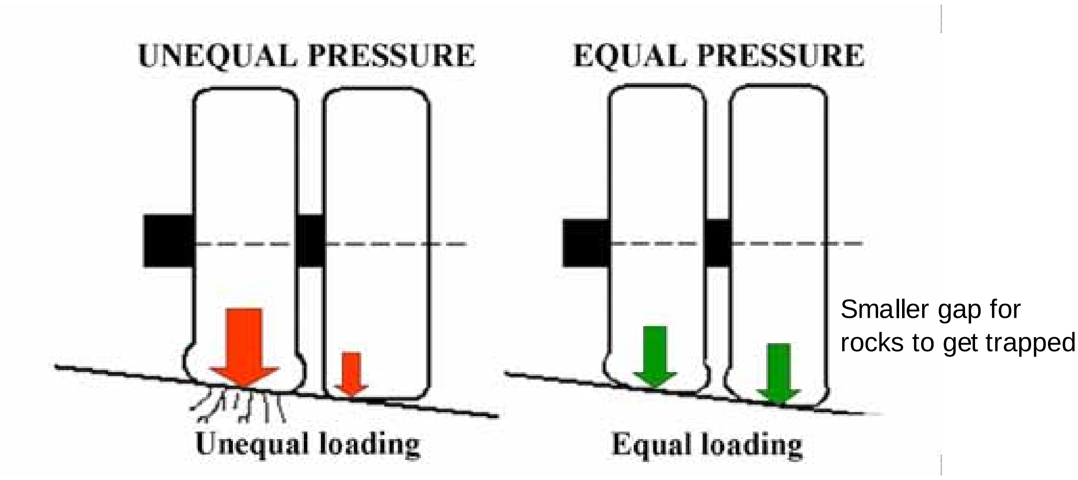
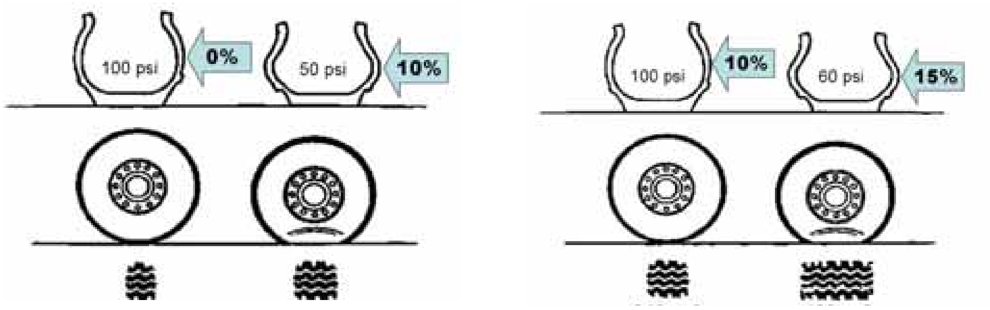


Figure 2.3 Effect of equal pressure in twin tyres on a crowned road (TPC International)

This "road crowning" produces unequal load sharing across twin tyre assemblies (in red) that results in unequal tyre pressure distributions between the tyres resulting in irregular tyre wear and increased stresses on the road. With TPCS, the controlled tyres have balanced pressures and equal loads, regardless of the shape of the road, and this creates better conditions for even tyre wear. It is also reported that the increased sidewall deflection under controlled pressure minimises the potential for sharp stones to get caught between the tyres (in green in Figure 2.3) (Weyerhaeuser trials).

Less noteworthy, but a consequence of TPCS nevertheless, is that lower inflation pressures tend to reduce damage to tyres on rough roads, both in the tread and sidewall, and the increased tyre sidewall flex of lower tyre pressures dampen vibration and create a smoother ride for drivers, “like adding another shock absorber”.



Unloaded Tyre Deflection Loaded Tyre Deflection

Figure 2.4 Effect of lowered tyre pressures on tyre sidewalls (TPC International)

2.2 BENEFITS CLAIMED FOR TYRE PRESSURE CONTROL

TPCSs generally are stated to offer a number of benefits to the vehicle owner/operator and driver:

a) On main roads TPCS is stated to offer improved vehicle responses at speed. A TPC system can control the inflation pressure within the loaded tyre to better achieve the manufacturer’s recommendations for tyre pressures and so produce a better tyre/road contact patch on the road surface. This results in optimum conditions for “mileage performance, comfort, transmission of traction and braking” as reported by Michelin in 2.1 above. Further, by having lower tyre pressures when travelling unloaded, the vehicle can ride over greater irregularities in the road surface, reducing induced vibration in the vehicle, and less impacts on the driver and vehicle.

b) Off road, the flexible tyres and longer footprint created by lowered pressures are said to offer the low speed characteristics of flexibility and improved traction for rough and weak forest roads that help to reduce tyre slip, negotiate loose, undulating, stony surfaces without damaging tyres. In these situations the lower pressure in the tyres make the tyres more flexible so that they adapt more readily to sharp aggregates

c) Tyre management. TPCS is said to offer extended tyre life, particularly the drive tyres that take the greatest punishment. This is stated to be due to the tyres being constantly monitored at their optimum inflation pressure resulting in better, even tread wear, less tread damage and chunking, and fewer blowouts due to overheating. In the event of minor punctures or leaks, the vehicle can continue working, or limp back to the workshop, so saving operational hours and costs of roadside repairs. Additionally less man hours are needed for tyre pressure checks in workshops as this is done automatically within the system.

d) Ride quality. Because tyres controlled by TPCS are at their optimum pressures vehicle handing on both main roads and rough roads is maximised. Low pressure tyres are also said to better deal with bumps and rough surfaces, minimising vibration into the truck and driver.

e) Driver health & safety. Improved driver health & safety is consequence of reduced vibration in the vehicle and fewer incidents of vehicles getting stuck and requiring heavy recovery.

f) Vehicle vibration. As above

g) Cost. Incorrect inflation pressures are said to result in increased tyre wear and shorter tyre lives. In addition better, and longer, footprints on rough roads are said to minimise wheel slip and tyre wear. Reduced vibration in the vehicle should result in fewer mechanical breakages and improved conditions for the driver.

This report will try to address these statements in the Highland trial and NPP area.

2.3 TPCS DEVELOPMENTS IN CANADA AND SWEDEN

Tyre pressure control technology is not new across the world. A brief history of the development of the technology has been kindly prepared by Allan Bradley of the Forest Engineering Research Institute of Canada (FERIC) and is attached to this report at Appendix A. This sets out a concise summary of how variable tyre pressure technology, central tyre inflation systems and tyre pressure control systems have developed since the 1940's, in both civilian and military applications and gives a number of useful references and papers for further reading. TPCS are now available worldwide.

TPCS in Canada

TPCS is now firmly established as a vehicle enhancement in north America with over 2500 trucks having been fitted with TPCS and a wide range of technical papers have been published by FERIC and other institutions that record the Canadian experience on its use since 1990.

Perhaps the most notable recent development in Canada is the acceptance by the Ministry of Transportation of British Columbia to permit the use of automated tyre pressure control systems on rural roads ("back roads") to permit heavy hauling during periods that were previously closed during winter. The Press Release announcing the new policy from the Ministry of Transportation, Ministry of Public Safety and Solicitor General, Victoria, dated 18 February 2004, opened with the statement:

> "*The province has approved the use of automated tire pressure control systems to allow industrial hauling on back roads during previously closed time periods, helping to increase opportunities for B.C.'s natural resource industries. This new policy will permit hauling during part of the spring load restriction periods, while protecting the province's road infrastructure."*

The full Regulation from the Ministry of Transportation of British Columbia on the exemption of TPCS with monitoring equipment from seasonal load restrictions is attached to this report at Appendix B.

In addition to the exemption in BC, the Canadian Province of Saskatchewan has introduced a 'trucking partnership programme' in which participants are permitted to drive oversize or overweight vehicles on approved routes. Under this programme overweight vehicles are charged an incremental ‘damage fee’ to compensate for the extra road damage they cause. A large scale field trial in 2000, in conjunction with the Manitoba Department of Infrastructure and Transportation and Michelin, demonstrated that TPCS more than compensated for the extra weight permitted and as a result TPCS vehicles in the trucking partnership programme are not charged for incremental road damage in the spring or the rest of the year. (Bradley 2000)

Also in Canada, The Manitoba Department of Infrastructure and Transportation is currently considering introducing a trucking partnership programme similar to that in Saskatchewan. A large research project is presently underway in the Province to look at the question of TPCS exemptions for incremental damage fees and the intention is to develop a TPCS Seasonal Loading Restriction hauling policy by 2009/2010. The Ontario Ministry of Transportation and the New Brunswick Department of Transportation are also involved in trials with FERIC to develop seasonal load restriction policies for trucks equipped with TPCS. Both Provinces have now conducted one successful field trial in conjunction with FERIC.

A summary of some recent TPCS trials carried out in North America is appended at the end of Appendix F, “TIREBOSS TPC spreadsheet”, courtesy of Tire Pressure Control International.

TPCS in Sweden

Sweden is the only country in the Northern Periphery that has trialled the use of TPCS in non-military uses. The Forest Research Institute of Sweden (Skogforsk) has been carrying out research on the use of TPCS on timber hauling operations since 1993 and, like Canada, has published a number of very useful reports on trials in collaboration with the Swedish Road Administration (Vägverket). Especially interesting have been the comparative trials of twelve timber haulage vehicles in 2006 that covered over 5 million kilometres of travel with TPCS. These trials compared the performance of the trucks, both super single and twin-tyred, with and without TPCS. They found that the tractive force developed by the TPCS vehicles increased by up to 55% when the tyre pressures were reduced. Drivers of these vehicles reported that their vehicles had better grip on slippery roads, thanks to the greater contact surface between tyre and ground at low tyre pressures. The Swedish forestry companies involved mentioned improved mechanical reliability, low repair costs, improved driver comfort, reduced tyre wear and lower fuel consumption. Swedish TPCS vehicles are accredited by “Bilprovningen”, the vehicle inspection company appointed by the Swedish government responsible for inspecting all vehicles registered in Sweden, and carry the vehicle documentation shown in Appendix D “accreditation of Vehicles Equipped with TPCS in Sweden” issued by the Swedish Road Administration..

Additionally in some novel investigations into vibrations induced into vehicles, which are still continuing, (Granlund, 2007), it was found that the TPCS system had a measurable secondary effect in reducing the vibration felt by the driver in the cab. Here it was found that a TPCS system could utilise the shock absorption capabilities of lower pressure tyres and could reduce vibration in the cab by up to 8%. A range of road types and vehicle speeds were tested and the greatest reduction in vibration was obtained when the vehicle was unloaded and operating on a rough, pot-holed gravel road that still permitted relatively high speeds.

As a result of these trials, the Swedish Road Administration has recently issued new regulations for vehicles equipped with TPCS as attached at Appendix C. This new 2007 regulation applies to vehicles travelling on roads with bearing capacity Class 2 or Class 3 when they are subject to weight or vehicle restrictions. The effect of the regulation is to remove a vehicle fitted with TPCS from the restriction and allow it to use the restricted road as if it was Class 1 bearing capacity road even though the vehicle is above the restricted weight for the road or section in question. The conditions of the Regulation are:

- TPCS must be fitted to all wheels on the vehicle
- all axles except the front axle must have twin-wheels
- the maximum tyre pressures shall be 600 kPa on the front axle, 400 kPa on the remaining tyres of the tractor unit, and 500 kPa on the tyres on the trailer
- the highest speed shall be 50 kph
- documentation shall be recorded for gross weight, time, road and tyre pressures
- documentation must be saved for at least three months and given to SRA if so requested.

Under this regulation, vehicles with a GTW of 60 tonnes will be permitted to travel on roads that, owing to a poor bearing capacity and/or an inadequate wearing course, would normally be restricted to traffic having a GTW of 52 or 38 tonnes. The Administration will also consider giving a dispensation (under certain conditions) to vehicles with a GTW of 60 tonnes equipped with TPCS to travel on roads that would normally be closed during the spring thaw. Spring 2008 will be the first test of relaxation for TPCS vehicles for the spring thaw season and the feedback is eagerly awaited. The Regulation also offers an exemption to TPCS vehicles on roads that have a weight restriction all year round.

Chapter 3. THE HIGHLAND TRIAL

3.1 THE AIM OF THE HIGHLAND TRIAL

The aim of the Highland trial was to evaluate the effects, and any benefits, of using variable tyre pressure control on a timber haulage vehicle on weak, low volume, public roads in the Scottish Highlands. It was planned that the trial would examine the effects of the trial on the vehicle as well as that of the road. For the road this would mean examining parameters such as deformation, stripping, overrun, etc, and for the vehicle parameters such as tyre wear, fuel consumption, ride comfort, whole body vibration would be considered.

Two reports are being issued on the trials:

a) A report Road owner that will deal with the impact on the road (published separately as the ROADEX III report “Developing and applying a basic understanding of low volume pavement behaviour”)
b) A report for road users that will deal with operational issues of TPCS and its perceived advantages and disadvantages to the vehicle owner, operator and driver. This report fulfils this role.

It was accepted at the outset of the trial that some aspects of TPCS would be difficult to assess quantitatively based on the effects of a single vehicle and some results were likely to be general perceptions rather than hard data. Good record keeping would be essential and the driver would be an essential player in the testing process to ensure that robust data could be obtained. Fortunately the driver allocated to the work, Mr Peter Dowson, was very interested in TPCS equipment and trials and the authors gratefully acknowledge his valuable input into the trial.

The trials had 2 aims:

1. To introduce TPCS to the Scottish forestry industry, and to the Scottish Highlands in particular; and
2. To trial the performance and reliability of the TIREBOSS system.

3.2 TEST VEHICLE AND LOAD

The primary test vehicle used in the Highland trial was a Scania 164L 580 6x2 tractor unit with a 25/26 tonne payload, tri-axle, twin tyred trailer operated by GA Mackenzie of Kinbrace, as shown in Figure 3.1 below. This vehicle was working under a sub-contract to James Jones & Sons Ltd who had successfully tendered and won the “Long Term Timber Contract” from Forestry Commission Scotland to harvest and process the timber plantations at Syre.

The “TIREBOSS” TPCS system, manufactured by Tire Pressure Control International Ltd of Edmonton, Alberta, Canada, was selected as the preferred system to be used in the Highland trial as a result of discussions within ROADEX with the Swedish Forest Agency. The Forestry Research Institute of Sweden had been carrying out trials with TPCS since 1 and had built up a considerable experience of the types of system available on the market and how they could be best used. Using their experience of TPCS, a TIREBOSS 2 valve system was fitted to the test vehicle in the week commencing 4 September 2006 and timber haulage using TPCS commenced on 9 September 2006. This date was taken to be the formal start date for the Highland trial. On 24 October 2006 new tyres, supplied by Michelin UK, were fitted to the test vehicle and this date was taken as the formal start date for the monitoring of tyre performance in the trials.

Figure 3.1 Photograph of the loaded test vehicle operated by G A Mackenzie of Kinbrace.

All wheel loads were measured at the commencement of the test by an officer from the UK Vehicle and Operator Services Agency. The gross train weight of the test vehicle was 42,875kg and the measured axle loadings and tyre arrangements are shown in the schematic underside view in Figures 3.2 below.

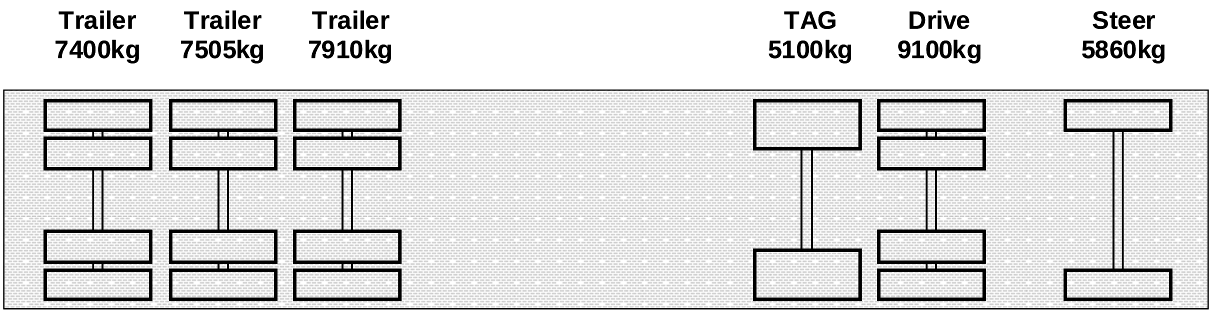


Figure 3.2 Schematic of underside of the loaded test vehicle showing the measured axle loads in kg

3.3 THE TEST VEHICLE HAULAGE ROUTE

The haulage route of the test vehicle is shown in Figure 3.3 below. The test vehicle was tasked to transport cut timber from the forests at Syre in central Sutherland to the Norbord ‘oriented strandboard’ manufacturing facility at Dalcross, Inverness. The journey comprised an overall return distance of 345km.

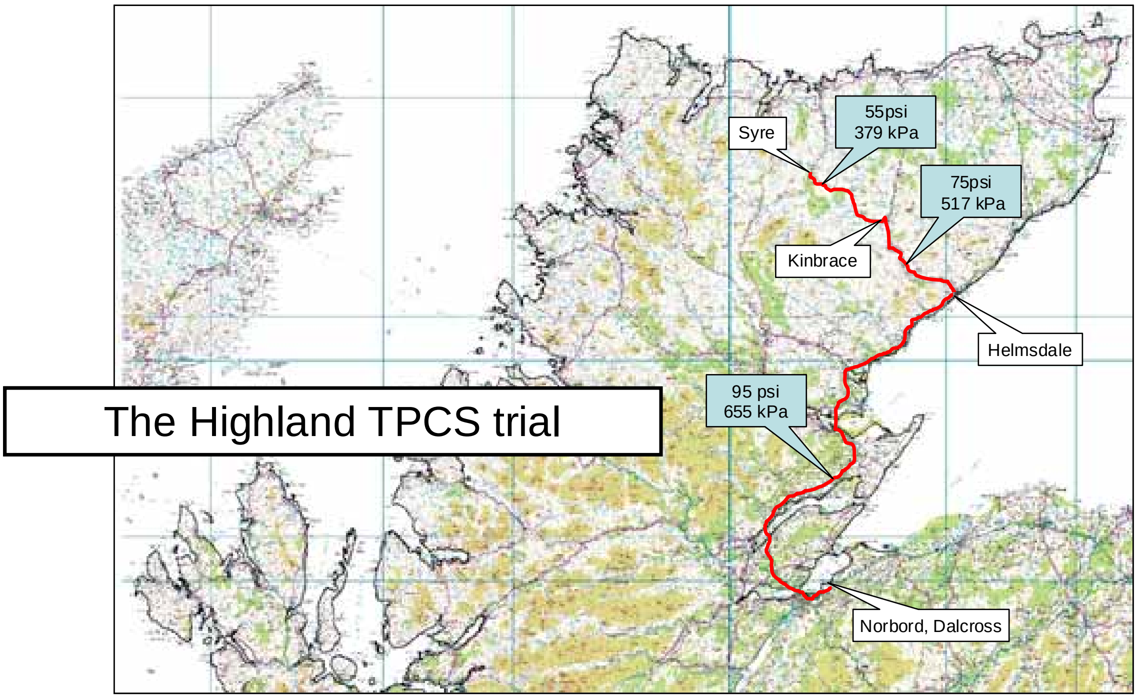


Figure 3.3 Loaded test vehicle loaded haul route from Syre in Sutherland to Norbord, Dalcross

For the purposes of report the start of the timber haulage route under study was taken to commence with the vehicle unloaded at Dalcross.

The test vehicle journey from this start point was as follows:

- travel unloaded 165 km north to Syre using a tyre pressure of 60 psi (414 kPa), 2hrs 30mins;
- load approximately 30 tonnes of timber in the forest at Syre;
- travel loaded 5 km on the unbound gravel roads within the forest using a tyre pressure of 40 psi (276 kPa), 10mins;
- travel loaded 25 km on the weak B871 public road from the forest entrance to Kinbrace at a maximum speed of 60kph using a tyre pressure of 55 psi (379 kPa), 35mins;
- travel loaded 30 km on the A897 to Helmsdale at a maximum speed of 60kph using a tyre pressure of 75 psi (517 kPa), 30mins;
- travel loaded 120 km on the A9 Trunk Road to Inverness and A96 to Dalcross, average speed of 80kph, using a tyre pressure of 95 psi (655 kPa), 2hrs;
- deliver the payload to the Norbord facility, Dalcross, total travel time 5hrs 45 mins.

A typical return journey following this schedule, excluding the driver’s statutory rest breaks, is shown schematically in Figure 3.4 below.

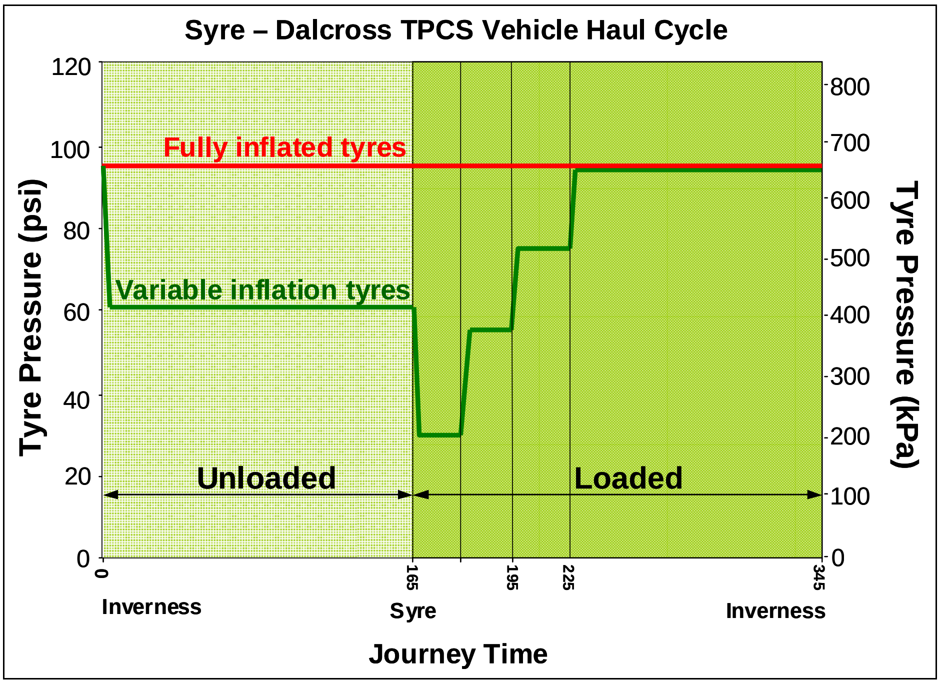


Figure 3.4 Test vehicle haul cycle from forest to Norbord processing plant, Dalcross, Inverness

This diagram shows the vehicle journey controlled by TPCS as a thick green line and that of the comparable standard journey with fully inflated tyres as a thick red line. The light green shaded section on the chart indicates the unloaded portion of the journey from Dalcross to the forests at Syre and the dark green shaded section shows the loaded journey to Dalcross. The difference between the green and red lines indicates those sections of the journey where proponents of TPCS argue that the tyres on the vehicle were over-inflated. In the case of the haul route shown in Figure 3.4 this means 65% of the journey is argued to be over-inflated. The TPCS trials on the route commenced on 9 September 2006.

3.4 THE TYRE PRESSURE CONTROL SYSTEM TESTED

The TPC system installed on the test vehicle was a “TIREBOSS TPC-TBM210 Truck and Trailer Control 2 valve system” as manufactured by Tire Pressure Control International Ltd of Edmonton, Alberta, Canada. Under this system one valve controls the tyre pressures on the drive axle and TAG axle of the tractor unit, using a common supply line, and the second valve controls all of the tyres on the 3 trailer axles again with a common supply line. The tyres on the steer axle on the test vehicle were not equipped with TPCS, but could have been by the use of a 3rd valve. The TIREBOSS system can be configured in one, two or three valves controlling up to 3 separate groups of tires. The tyres on the steer axle were not controlled by TPCS.

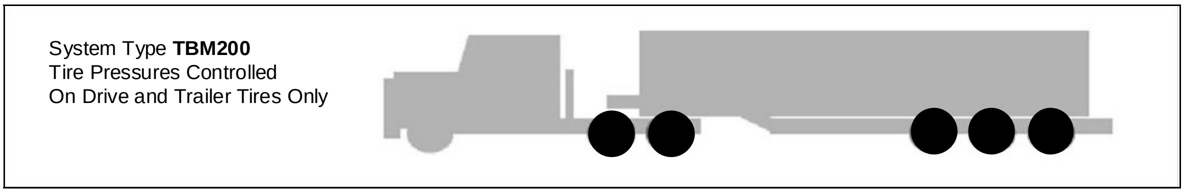


Figure 3.5 Vehicle axles fitted with TIREBOSS

The TIREBOSS system used in the trial was retro-fitted on to the test vehicle but it can also be factory fitted to new vehicles. The system comprises a controller in the vehicle cab, a valve box installed on the vehicle chassis, axle fittings and wheel shut-off valves together with Department of Transport approved hoses connecting everything together as shown in Figure 3.6 below.

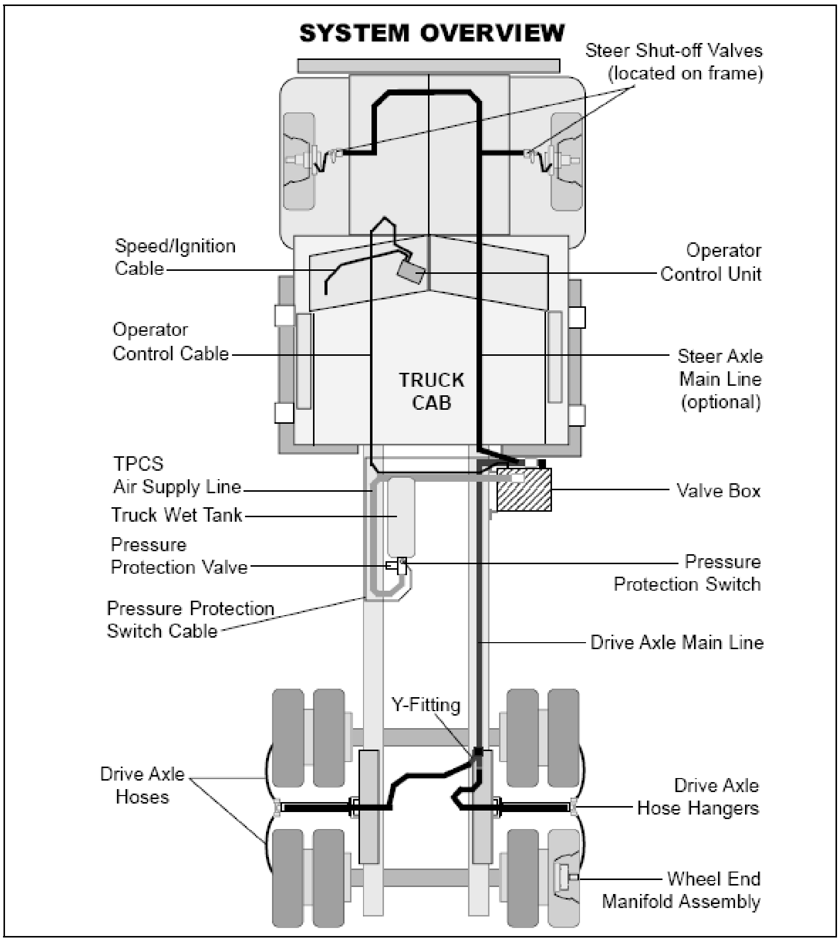


Figure 3.6 Schematic diagram of a TPC system on a tractor unit (TPC International)

The two valve system fitted to the test vehicle permitted 2 tyre pressure control circuits to be set up on the vehicle, one for the rear axles of the tractor unit and one for the trailer. The steer axle on the trial vehicle was not equipped with TPCS. For the purposes of the Highland trial it was decided at an early stage that all tyres controlled by TPCS on the test vehicle should be inflated to the same pressure

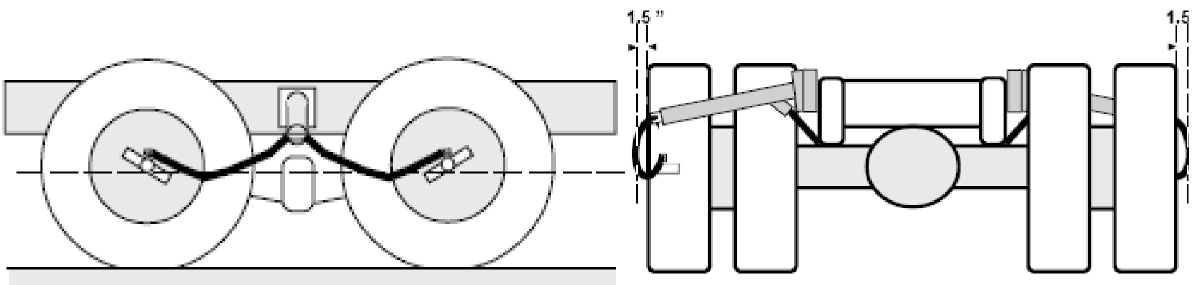


Figure 3.7 Schematic diagrams of a TPCS air hose arrangements on a tractor unit (TPC International)

3.5 TEST VEHICLE TYRES

Early on in the planning of the Project it was thought prudent to involve a large tyre manufacturer in the trial in order to have a professional involvement in the assessment of tyre wear. Michelin UK, as the main suppliers of tyres to James Jones & Sons, were asked if they wished to co-operate in the trials and technical assistance was quickly offered by their Technical Manager, Dan Lamb. The matrix shown below is one of 4 matrices suggested by Michelin UK on 11 May 2007 for their tyres in the TPCS operations of the test vehicle. The full suggestion from Michelin UK is attached at Appendix E to this report. The matrices have been designed for the particular arrangement and loading of the test vehicle and its expected usage. The design of the matrices has taken into account the possibility that the twin tyres of the trailer may touch.

Michelin suggested that the tyres on the drive and TAG axles should be inflated to the same pressure and a separate pressure setting was suggested for the trailer. The pressures in the table are stated in 'pounds per square inch' (psi) with the kPa equivalent stated in parenthesis alongside.

The matrix used in the trial was Matrix 2, "Cold tyre pressure suggestions for a system that corrects itself for temperature increase for a vehicle that does not adjust Steer Axle tyre pressure and adjusts axles 2 and 3 to the same pressure", is copied below as Table 3.1. This matrix was designed for the TIREBOSS '2 valve' system as used on the test vehicle where the tyres on the steer axle are not part of the system. The TIREBOSS TPCS uses the cold tyre inflation pressures suggested by tyre manufacturers. Typically tyre manufacturers specify cold inflation pressures for heavy vehicle tyres in the expectation that these tyres will heat up in the course of their duties over a couple of hours and that the tyre inflation pressures will increase by 15% to 20%. This higher pressure, of the heated tyre at work, is the designed tyre inflation pressure used by the tyre manufacturer to get the optimum performance from the tyre. A main source of tyre heating for heavy vehicle tyres is heat generated by braking which is then transmitted through the wheels to the tyres. The settings of the TIREBOSS program allow for normal heat build-up in all of the controlled groups of tyres but also incorporate over-riding safety features to deal with extreme situations. For example if the pressure in the tyre exceeds a maximum limit, a "Tyre Overheat" alert is displayed indicating an overheating condition in the tyre which may be caused from improper pressure settings or a failure of other vehicle components, such as the brakes overheating. This advises the driver to stop and check the cause of the excess pressure.

Table 3.1 Cold Tyre Pressure Suggestions for a system that corrects itself for temperature increase for a vehicle that does not adjust Steer Axle tyre pressure and adjusts axles 2 and 3 to the same pressure

Axle	*Tyres*	*Axle Load (kg)*	*'A' road, unladen to Syre (90km/h)*	*Fully laden in forest - gravel road (25 km/h)*	*Minor public road - sealed (50 km/h)*	*'A' road, narrow & bendy (70 km/h)*	*A9 Trunk road laden (90km/h)*
Steer axle	295/80 R 22.5 XZE2	5860	125 (862)	125 (862)	125 (862)	125 (862)	125 (862)
Drive axle	295/80 R 22.5 XDY	9100	50 (345)	35 (241)	75 (517)	75 (517)	80 (552)
Tag axle	385/65 R 22.5 XZY3	5100	50 (345)	35 (241)	75 (517)	75 (517)	80 (552)
Trailer	11 R 22.5 XTE2	7600	60 (414)	35 (241)	54 (372)	80 (552)	80 (552)

As a result of this Michelin matrix, and other advice, the tyre pressures on the test vehicle were allocated TIREBOSS settings of 60 psi (414 kPa) unloaded, 55 psi (379 kPa) on forest roads and the weak B871 road, 75 psi (517 kPa) on A897 and 95 psi (655 kPa) on the A9 and A96 Trunk Roads as below.

Table 3.2 TIREBOSS tyre pressure settings on the Highland test vehicle

Axle	Tyres	Axle Load (kg)	'A' road, unladen to Syre (90km/h)	Fully laden in forest - gravel road (25 km/h)	Minor public road - sealed (50 km/h)	'A' road, narrow & bendy (70 km/h)	A9 Trunk road laden (90km/h)
Steer axle	295/80 R 22.5 XZE2	5860	125 (862)	125 (862)	125 (862)	125 (862)	125 (862)
Drive axle	295/80 R 22.5 XDY	9100	60 (414)	35 (241)	55 (379)	75 (517)	95 (655)
Tag axle	385/65 R 22.5 XZY3	5100	60 (414)	35 (241)	55 (379)	75 (517)	95 (655)
Trailer	295/80 R 22.5 XZE2	7600	60 (414)	35 (241)	55 (379)	75 (517)	95 (655)

Percostation

The test site Percostation was manufactured by the Estonian company Adek Ltd and supplied by Roadscanners Oy of Finland. The station utilised 5 sensors below the road, installed at 150, 300, 450, 600 and 900mm below the road surface, to monitor the dielectric value, electrical conductivity and temperature of the materials within the road construction layers and subgrade. Measurements were taken automatically by the station at 2 hour intervals and the results saved in the station's memory until they were read via wireless modem. The Percostation has a solar panel array to supply its power.

The Percostation had previously been installed on the B871 public road at Garvault to monitor changes in dielectric values, electrical conductivity and temperature in the road layers, subgrade soils and air temperature over the two winters 2002 – 2004.

According to the Percostation results the critical time on the B871 road over the winter 2003-2004 was from mid December to mid February (Figure 1.5), after that period there were still some frost nights but the temperature in the layers were sufficiently high to prevent cryo-suction affecting the moisture content. Results from the following winter of 2004-2005 showed that the critical period could last up to mid March. This work is reported in the ROADEX II publication "Managing Spring Thaw Weakening on Low Volume Roads" by Saarenketo & Aho (2005) and in internal reports of The Highland Council.

Chapter 4. Results

4.1 GENERAL

As already mentioned the Highland trial had 2 aims: to investigate the effects of TPCS on the road from the point of view of the road owner, and to investigate its effects from the point of view of the road user. The effects of TPCS on the road generally, and including the road responses from the A987 trial, is considered in the separate ROADEX III Project Task B2 report "Understanding Low-Volume Pavement Response to Heavy Traffic Loading" by Andrew Dawson, Pauli Kolisoja & Nuutti Vuorimies. This report will concentrate solely on the use and perceived benefits of TPCS from the perspective of the vehicle operator and driver. These will be considered under the following headings:

- Costs
- Vehicle performance
- Tyre performance
- Perceptions of operators
- Tyre inflation time
- TPCS reliability
- Fuel consumption
- Impact on roads travelled

4.2 COSTS

The first question that any intending user of TPCS will invariably ask will be "How much will it cost?" and "Why should I pay for something that will benefit roads?" If the system cannot be seen to be cost effective to the haulage contractor, for the additional expenditure incurred, it will not be bought. So cost, and the likely return on investment, has to be addressed at the outset.

Capital Cost

The capital cost of the system is relatively easy to determine. The "TIREBOSS TPC-TBM210 Truck and Trailer Control 2 valve system" used in the Highland trial was purchased for 16,000 C$ and locally retro-fitted in Scotland on to the test vehicle for approximately £2,500, ie a total installed cost of 15,000 €. The likely operational return for this investment is less simple to determine but it can be approximately estimated through a very useful spreadsheet prepared by the TIREBOSS manufacturer, Tire Pressure Control International Ltd, and the Forest Engineering Research Institute of Canada (FERIC) as below. A brief summary of the contents of the spreadsheet is attached at Appendix F and intending users of the TIREBOSS system may be able to obtain a copy of the spreadsheet from Tire Pressure Control International Ltd.

Return on Capital

The TIREBOSS spreadsheet was used to estimate the likely return for the TPCS system fitted to the Highland test vehicle, ie the single drive/TAG axle tractor unit with a tri-axle twin-tyred trailer. The following information was entered on to the spreadsheet: TIREBOSS installed cost of 15,000 €, 20 tyres on the test vehicle, a vehicle life of 5 years at 100,000 km/year, first tyre life 50,000 km, 25 tonnes payload, estimated average bogging and recovery incidents, estimated average tyre damage, standard UK labour costs, UK industry average operating hours and conditions, no improvement in fuel consumption. With this data input, the TIREBOSS spreadsheet estimated a capital cost payback of 4.8 years for a "medium duty" operation, ie 10%-30% of travel off highway, for no improvement in operating hours. This first estimation essentially considered the installed cost of the TIREBOSS system against the improvement in tyre and traction performance without assuming any gain in efficiency or productive hours. On this basis the TIREBOSS spreadsheet gave a marginally negative 'Internal Rate of Return' on the money spent.

If however some productivity improvements can be expected, and this appears likely on balance, (see contractors' comments in Section 4.3), the simple payback period may be able to be reduced depending on what productive hours are likely to be gained and this is shown in Figure 4.1 below. For example, if it is expected that an extra 50 productive hours can be generated with TPCS, through longer tyre life, fewer punctures and delays, bogging incidents, recoveries then the capital cost payback period reduces to 3.6 years (as shown by the red lines), with a consequent improved IRR of return on 5% on the capital employed. This gain would however have to be proven in practice with operational experience.

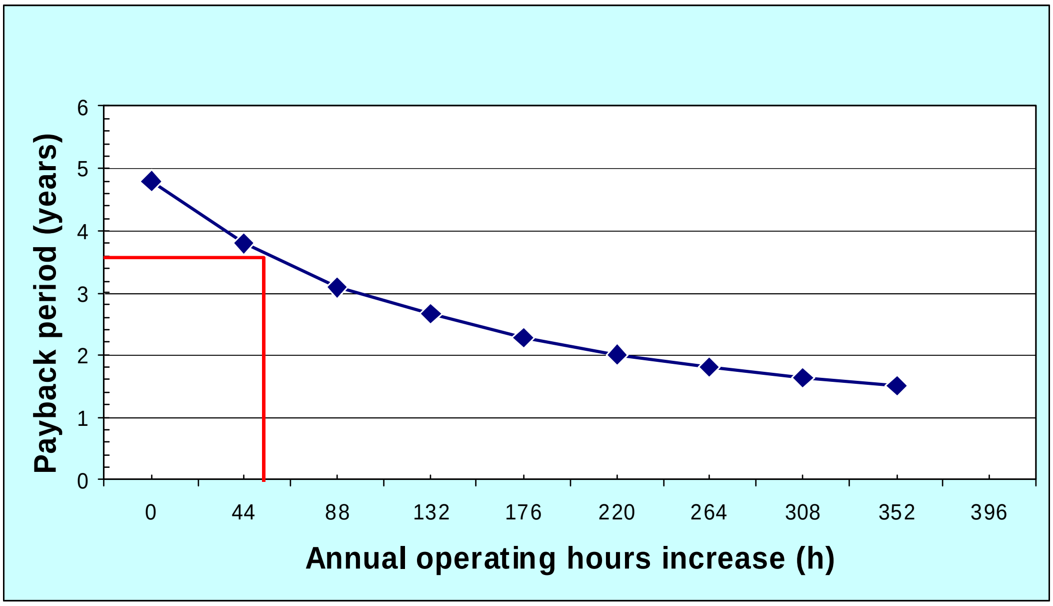


Figure 4.1 Payback years v. Annual operating hours increase for the Highland test vehicle, medium duty working (10%-30% off highway), no improvement in fuel consumption assumed

The TIREBOSS spreadsheet was also used to try to estimate the potential operational benefits for 2 new timber haulage vehicles purchased by James Jones & Sons Ltd, a 6x4 tractor unit with a tri-axle super single trailer and a 6x2 tractor unit with a tri-axle super single trailer, that were retro-fitted with a TIREBOSS 2-valve system in June 2007.

As with the Highland test vehicle, the 2 vehicles were assumed to have a vehicle life of 5 years at 120,000 km/year, 14/16 tyres, first tyre life 50,000 km, 25 tonnes payload, standard UK labour costs, UK industry average operating hours and parameters, no improvement to fuel consumption, being operated on a medium duty haulage operation, with no improvement in operating hours.

On this basis the TIREBOSS spreadsheet estimated a capital cost payback of 2.9 years for the 6x4 double drive vehicle combination and a payback period of 3.1 years for the 6x2 TAG single drive combination, again assuming no operational gains in productive hours or change in fuel consumption as these could not be confirmed.

Figure 4.2 Photograph of the loaded James Jones TPCS 6x2 TAG unit with super single tri-axle trailer during hauling operation on the A897 public Road, July 2007

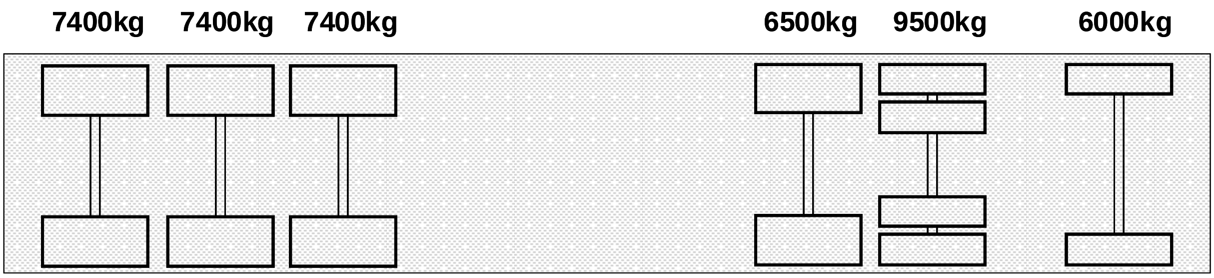


Figure 4.3 Schematic of James Jones TPCS 6x2 TAG unit with super single tri-axle trailer

In all of the above estimations is has been assumed that the cost of the TIREBOSS system has to be recovered against the first use before being scrapped. This may be an overly conservative assumption as a retro-fitted TIREBOSS installation can be removed and re-installed in other vehicle for re-use. Experience in Sweden has already shown that the system is capable of 3 uses and in Canada, where the TPCSs have been around since 1993, (TIREBOSS since 1996), systems have been successfully re-installed on up to 5 vehicles.

4.3 VEHICLE PERFORMANCE 2006-2007

The daily performance of the test vehicle was not recorded in detail, as resources were not sufficient to do this, but a number of perceptions were gathered that give insights into the success or otherwise of the TIREBOSS TPCS in improving vehicle performance.

The tables that follow record the comments of Gordon A Mackenzie (GM), owner of the test vehicle, Peter Dowson (PD), driver of the test vehicle, and Jonathan Ritchie and Aaron Skene (JJ) for James Jones & Sons Ltd, on the stated benefits of TPCS.

Table 4.1 Perceptions on the effects of fitting TPCS on vehicle performance

Vehicle performance	Comment
Improved traction and braking?	*GM: Yes, traction has definitely been improved. Two vehicles were used on a contract in Perthshire, one standard 6x2 and one 6x2 with TPCS. The standard vehicle got stuck, spun its tyres, rocked the vehicle, generally struggled and lost time, a potential accident. The vehicle with TPCS went straight in and out again without difficulty. Braking should be better as a greater tyre contact area is on the road.* *PD: Yes, noticed it straight away in sand, loaded, at Lossiemouth. A double drive Foden got stuck in the sand and the driver could not believe my vehicle got through.* *JJ: Yes, at Tomintoul 2 vehicles were sent to pick up from the forest, a double drive with TPCS and a double drive without TPCS, both with the same configuration. The double drive vehicle without TPCS went into the forest unloaded but then got stuck on the way out o a steep gradient (approx 10%). A John Deere tractor tried to give assistance and pull it out but without success. Half the load was taken off and the tractor just managed. The vehicle with TPCS did not have a problem. This has been recorded on video.*
Reduced need to provide assistance on steep gradients?	*GM: Yes, this was proven at the "Confor" demonstration trials at Eskdalemuir.* *PD: I stopped the vehicle for a test on a steep grade, approx 1 in 8, in Locherbie Wood at the "Confor" trials and then pulled away. The wheels did not spin. The spectators watching were impressed.* *JJ: Yes, as at Tomintoul above. Also at Deishar wood, the same 2 vehicles had an equal experience on steep, muddy roads. Two double drive vehicles without TPCS needed to have 1,500€ of new tyres each after the work. The double drive vehicle with TPCS had no problem.*
Fewer bogged vehicles requiring rescue by forwarder?	*GM: We have had one bogging incident in 13 months vehicles since fitting TPCS. Previously this would have been 5 or 6 times. TPCS could get stuck on mixed use roads if normal vehicles undo the good work by TPCS.* *PD: Yes, I have been in woods where other vehicles were getting bogged down but I got the load out without assistance. At Grantown-on-Spey the forwarder had put the wood further back and the other timber vehicles had to unload to get out, but I got the full load.* *JJ: None so far after 4 months using TPCS on 2 vehicles.*
Higher vehicle capabilities, more locations possible?	*GM: Yes, definitely. It is now possible to build a reduced standard road to meet the capabilities of the TPCS vehicle. The last sections of the*

	forest road at Syre were not improved before harvesting. This has saved FCS money as the TPCS vehicles did not need a higher standard of road. *PD: The vehicle is now sent to places where other vehicles get stuck. One site had the stockpile off the end of the road. I reversed off the road to the stockpile, let the tyres down to load and then pulled away. On soft ground I now load with 35 psi (241 kPa) pressure in my tyres.* *JJ: Definitely. One vehicle went into a field to get to a timber stockpile!*
Longer haul seasons?	*GM: Yes. The Highland Council have agreed lifted the winter weight restriction on the B871 for our vehicles fitted with TPCS.* *JJ: Yes. FCS stop vehicles using roads when they are weak during thawing. We are looking for FCS to exemption TPCS vehicles from these winter restrictions.*

Table 4.2 Perceptions on the effects of fitting TPCS on ride quality

Ride quality	**Comment**
A smoother and more stable ride?	*GM: Yes, but it possibly could have been even better if TPCS had been fitted to the steer axle. Better for the driver and the road. I would like to try one to see the effects it had.* *PD: Yes, it has to be slightly better than before particularly in the wood. The vehicle now glides over rough ground.* *JJ: Yes.*
Higher average speeds on rough roads and reduced haul times?	*GM: We are still running with the steer tyres fully inflated and still hitting the potholes.* *PD: Higher speeds only do damage.* *JJ: Yes, lower vibration and a smoother ride wil enable drivers to go faster but safely.*
Decreased damage from shocks and vibration?	*GM: We have had no unexpected failures after 13 months of trial. The springs on the elderly trailer were expected to fail. Since new springs have been fitted there have not been any problems, no light bulbs, no shock absorbers.* *PD: None, apart from the old springs that were on the vehicle when the TPCS was fitted. Since these were replaced there have been no breakages.* *JJ: Yes, we are not replacing bulbs, tightening shock absorbers, tightening loose bolts. We are always tightening loose parts on vehicles without TPCS.*
Reduced stresses on the transmission with fewer failures?	*GM: There have been problems with the clutch, differential and gear box but the vehicle is not new. These were expected.* *PD: No problems.* *JJ: cannot comment yet.*
Reduced repair and maintenance costs?	*GM: I would expect reduced costs but my vehicle was not new. Can only really compare like for like.* *JJ: Probably, as there are not so many tyre changes, time is not taken up changing bulbs, tightening wing poles, etc*
Reduced down time, more productive hauling?	*GM: Yes, we have had fewer tyre changes. Has to be better, do not get stuck now or have wheel spin. Two minutes of wheel spin can*

	mean 1,000 km of tread wear. *PD: Yes, do not get stuck.* *JJ: Yes, everything is interconnected. Less maintenance, fewer times stuck must result in reduced down time and more productive hauling.*
Longer vehicle service life?	*GM: This hasn't proven yet. I would expect a longer vehicle life but we did not start with a new vehicle so I can't say. Can only really compare like for like.* *PD: Possibly, we are no longer getting damage up through the vehicle and breaking springs, but there would need to be comparative tests to prove this. The "Tireboss" system has only required regular greasing.* *JJ: This is very likely. Less vibration means fewer cracks developing in the trailer chassis. There have been no cracks in the trailers with TPCS yet. At present we generally consider a useful life of 5 years for the tractor unit and 7 years for the trailer. But we will look closely at this to see if we can get another year out of a TPCS outfit. It is a possibility.*

Table 4.3 Perceptions on the effects of fitting TPCS on the Driver

Effects on the driver	**Comment**
Reduced driver fatigue?	*PD: A bit easier on the driver. I don't seem to be as tired after a shift. I used to need to stretch after 4 hours driving but it is not so bad now.* *JJ: One driver has said that TPCS is better. He does not go home with backache or as tired as previously on non TPCS vehicles.*
More productive drivers?	*PD: I could not comment.* *JJ: The interesting thing here is that drivers have accepted the method, and are using the equipment, and are feeling the benefits.*
Fewer back problems?	*PD: Already have a back problem. But the vehicle is smoother on rough roads. It "wallows" over bumps.* *JJ: This is a long term issue but we certainly hope so.*
Safer working environment?	*PD: Yes, not getting stuck is safer. The majority of accidents occur during recoveries of vehicles.* *JJ: Yes. We now have confidence when we send out a driver with a TPCS vehicle and we know what the condition of the road will be. Previously we could send out 3 or 4 vehicles without problem but the 5th could wreck the road. This does not happen now as long as we do not mix vehicles.*

4.4 TYRE PERFORMANCE 2006-2007

New Michelin tyres were fitted to all wheels of the test vehicle on 26 October 2006 and a record was commenced of "vehicle distance travelled" versus the "remaining average tread depth" on the tyres of each axle by the vehicle owner. A table of the average tread depths recorded during the period is shown in Table 4.4 and the same information is shown graphically on Figure 4.5 as a chart of "Tyre tread wear v. Distance travelled" for each of the 6 axles of the vehicle. From this table and chart a number of matters can be discussed:

Table 4.4 Records of tyre wear on the test vehicle from 24 October 2006

Date	24/10/06	19/02/07	28/04/07	28/05/07	01/07/07	11/08/07	13/09/07	31/10/07	09/02/08
Km	423342	458536	479048	490304	502354	516524	526120	540078	569553
Axle	Average tread depth (mm)								
Steer axle	16	10	8	6	Damaged	n/a	n/a	n/a	n/a
Drive axle	19	12	9	7.5	Changed 4 to 22	19		Changed 16 to 9	5
TAG axle	17	14	12	11.5	11	9		8	6
Trailer axle 1	13	11	10	9	9	8		5	3
Trailer axle 2	13	11	11	10	10	10		7	6
Trailer axle 3	13	11	9	6.5	5	4	1 recut	3	n/a
Distance travelled		35194	55706	66962	79012			79012	108487
Tread wear on drive		7	10	11.5	15			15	19
Km/mm wear		5028	5571	5823	5267			5267	5710

(The beige cells indicate the period of time that the drive tyres were removed from the test vehicle for inspection by Michelin UK. The test vehicle travelled 37,724 km during the period.)

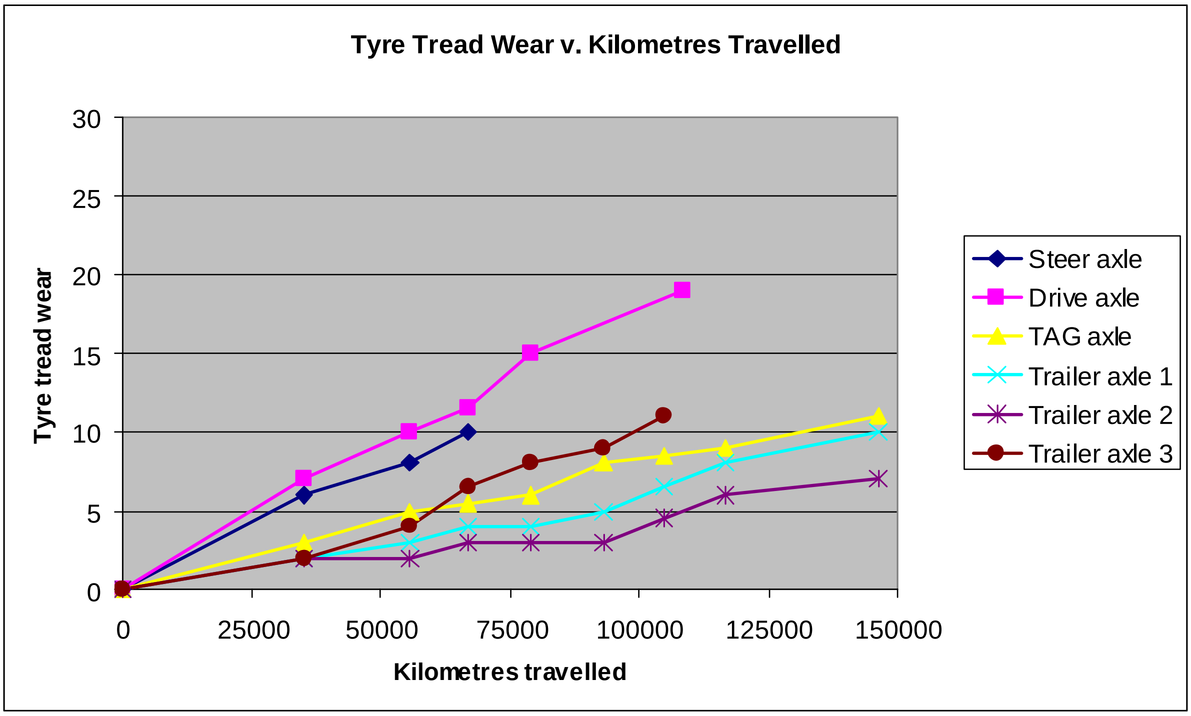


Figure 4.4 Graph of tyre tread wear v. distance travelled by test vehicle

Firstly it can be clearly seen the drive axle tyres experienced the fastest wear, from a tread depth of 19mm down to 4mm over 79,000km, and were the first to require replacement. These tyres were removed at a residual tread depth of 4mm, slightly earlier than normal, for the purposes of the test and investigation at the Michelin UK laboratories. It is generally expected that drive axle tyres will wear the quickest as these tyres are responsible for the torque and traction of the vehicle and are therefore subject to additional heating and greater movement of the tread blocks than that experienced by non-drive axle tyres. The reduction in the rate of wear of the drive tyres over the months of the test was similarly quite normal and was due to a reduction in movement of the tread blocks (tread shuffle) as the block depth reduced. This distance travelled was subsequently extended to 108,500 km by 9 February 2008, after regrooving by Michelin, with an expectation of a further 10,000 km with similar usage.


Figure 4.5 Photographs of the condition of the drive tyres of the test vehicle on 9 February 2008

The wear and damage to the steer axle tyres was also quite normal as these tyres experienced significant scrubbing forces during steer. The tyres on the steer axle were not controlled by TPCS and were not therefore considered as apart of the Highland trial. Experience gained from the steer axle during the trial however indicates that it may have been a better trial if all axles had been controlled with TPCS (see comments by G Mackenzie on "ride quality" in Table 4.2).

The tyres on the Tag axle, to the rear of the drive axle, appear at first glance to be less stressed that the tyres on the drive and steer axles, but when it is considered that the TAG axle was raised off the road for the unloaded length of journey from Dalcross to Syre (ie 50% of the overall journey), the tyres on the Tag axle can be seen to show significant wear from an original tread depth of 17mm to a tread depth of 11mm after travelling approx 40,000km. This is considered to be due to the regular 'scrubbing' of the Tag axle tyres on tight corners, such as at the B871/A897 junction south of Kinbrace. The surface of the road here shows numerous trails of thick tyre marks that indicate that significant scrubbing manoeuvres have taken place, see Figure 4.5 below.


Figure 4.6 Photographs of tyre scrubbing patterns at the B871/A897 junction at Kinbrace

The twin tyres of the tri-axle trailer give interesting wear rates. As would be expected the tyres on Axle 3, the rearmost axle of the trailer, show the greatest wear rate, followed by Axle 1, the front axle, and Axle 2 in the middle. This variation is accepted to be due to the respective scrubbing forces on the axles when cornering and is primarily due the configuration of the vehicle. Experience from Canada indicates that the additional wear on rear axle tyres can also be due to the result of these axles always running furthest from the centerline of the lane (tracking towards the ditch or "dog tracking" caused by road cross slope) where the road surface is roughest, softest, and most likely to have edge damage.

On 1 July 2007, the drive tyres were removed from the test vehicle and sent to the Michelin UK laboratory for testing and re-cutting of the treads if they were considered suitable. During this examination it was found that the tyres had been taken off the test vehicle slightly early. Michelin measured the remaining tyre treads at 5.6mm, 4.3mm, 5.4mm and 5.2mm for the 4 tyres examined. They generally recommend that tyres are removed at approximately 2-3mm. The tyres were inspected visually and by touch by Michelin and were reported as being "evenly worn and even across tread". The tread of one tyre was reported as being "*deeply cut due to contact with some fixed sharp or abrasive object and the bead of the tyre has been accidentally damaged during fitting or removal*" but was considered repairable. All 4 tyres were recut with an additional 4mm of tread bring the depth of remaining tread up to 9mm on average. Recutting of tyres of a timber haulage vehicle was unusual in itself for Michelin as in their experience non-TPCS tyres were very rarely recut due to their condition. In the experience of Michelin, tyres from timber haulage vehicles are normally so badly damaged that they are not in a fit state to be reused. Recutting aims to add 25% to the life of a tyre

The tyres on the test vehicle had previously been inspected by Michelin at the "Confor", (The Confederation of Forest Industries (UK) Ltd), "*Central tyre inflation in operation over wet ground*" demonstration at Eskdalemuir in Dumfries & Galloway, Scotland, on 21 February 2007. The Michelin UK Technical Manager, Product Marketing – Truck, reported that he and his colleagues were "*absolutely amazed the way the tyres had worn. Usually tyres in similar circumstances would have been badly worn due to the hard life they experience. The even wear on the TPCS tyres was rarely seen in timber operations. Tyres in these operations usually wear as a result of spinning from loss of traction. The TPCS tyres had virtually no damage when the wheel arch was taken off for inspection*."

Michelin also noted that in their experience tyres on tri-axle trailers wear at different rates. If the rear axle in a tri-axle arrangement is assumed to incur 100% wear, it is usual for the mid axle to incur 30% wear and the front axle 60-70% wear. Assuming that TPCS tyres from timber haulage vehicles can be reused, as with those of the Highland trial, Michelin recommend that tyres should be managed using the "4 Lives Strategy" of New - Recut - Remix - Recut" to give the optimum return on investment. "Remix" is the Michelin name for retreading or recapping a tyre. The Michelin suggestion for the optimum use of tyres on a tri-axle trailer is:

- Fit new tyres to the back axle
- Fit re-grooved tyres to the mid axle
- Fit Remix axles to the front axle

If this policy is not followed there is a possibility of the vehicle operator ending up with too many recut tyres with the risk of less rubber on the tyres, and a greater chance of damage to the tyre and tread blocks due to tread tearing.

On 13 September 2007 the tyres on Trailer Axle 3, the rearmost axle, were removed for inspection by Invergordon Tyres Ltd to see if the tyres were in a suitable condition for recutting the treads, as done with the drive tyres. This was the first time that the truck operator had considered recutting treads, as they had previously been too badly damaged to permit this option, but he was prepared to try the method to see what benefits, if any, could accrue from TPCS tyres. The cost of recutting the treads was stated to be approximately 25€ per tyre and there was a concern that the recutting exercise could damage the tyre casings which had a credit value of approximately 90€ against a new tyre.

All 4 tyres were reported to be in a good condition at the time of the inspection, although all exhibited some signs of scrubbing on the road surface. The depth of a typical inside groove of the tyre was measured by Invergordon Tyres to be 1mm deep and the outside groove (there were 6 grooves on the tyres) was measured to be 3mm deep. These measurements were reported to be unusual in the experience of the Invergordon Tyres. In their experience it was more usual to see a greater variation in tread wear, up to 6mm or even damage, in tyres from timber haulage vehicles as a result of scrubbing. The good condition of the tyres, which was common across the 4 tyres to be recut, was attributed to the TPCS on the vehicle. When the scrubbing evidence was reported to the truck operator he said that he knew was very aware of the problem as every sharp bend on the route to the Norbord plant was a right hand bend. This would have had a cumulative effect on the tyres, and they would have been far worse if their inflation pressures had not been controlled by TPCS. The photograph of the right hand bend immediately after Kinbrace in Figure 4.5 gives an indication of the type of scrubbing manoeuvre experienced on the route.

The tyres were recut by Invergordon Tyres to produce grooves 6mm wide and an additional 4mm deep. This was the first time that the company had recut tyres from a timber haulage vehicle but was considered appropriate in view of the good condition of the casings and the continuing trial of the tyres. It was suggested that the regrooved tyres should be refitted to the vehicle on “Axle 2” as this had the least stress and wear but as this was a trial the tyres were refitted to “Axle 3” to see how they performed.

Table 4.5 Perceptions on the effects of fitting TPCS on tyre management

Tyre management	Comment
Better overall wear rates even on rough roads	*GM: Definitely. The local haul route involves forest roads and weak public roads over peat. I have particularly noticed the difference in the twin tyres. In the past the inside tyres were very worn and the outside tyres could still have had 4mm left but this has changed with TPCS. The wear is now even.* *JJ: Yes, more even wear. Even the twin tyre assemblies are showing even wear on the inside and outside tyres.*
Fewer punctures?	*GM: Yes. We have had one puncture to date – a nail on the shoulder of the tyre. The puncture was patched but it failed, maybe due to the increased flexibility of a TPCS tyre. The vehicle worked on however even with the puncture.* *PD: I had one puncture on 19 June 2007 but continued to run the vehicle all day. There was no loss of performance or loads.*

	JJ: We have had only one puncture – a metal foreign object. Much less tyre damage.
Better tread wear?	*GM: Yes, the tyres are showing even wear across the tread and even wear across the tyres on an axle. Previously the inside tyres suffered greater wear. The old eccentric tyre wear on vehicle has not appeared.* *PD: Yes, previously one axle had eccentric wear.* *JJ: Tyres are not wearing as fast as they did. We are now over 4 months into our trials and tyres appear to be significantly better than before at a similar stage. They appear to be lasting better.*
Less tyre damage, fewer cuts and penetrations?	*GM: Far less damage. Dramatic difference in tyre damage. The local haul route involves forest roads and weak public roads over peat.* *PD: None after 80,000km on 26 June 2007. The front tyres (non TPCS) are suffering however.* *JJ: Yes at 4 months.*
Longer tyre life?	*GM: Yes, tyres are already better than expected and the recutting will probably bring another 20,000km. It is generally said that "if you are getting more than 50,000km you are doing well".*
Less downtime for tyre changes?	*GM: Yes. There have been less tyre changes. Less downtime for punctures. Tyre changes are taking longer however because of the need to strip the hubs, maybe ½ hour more. Now we change tyres and service the brakes at the same time. Maintenance tales longer, but it is not a problem.* *JJ: We are not changing tyres as frequently. We see a real improvement in the super single rear axle of the trailer. The edges of these tyres are not wearing as before.*

4.6 TYRE INFLATION TIME

The time required to increase the pressure in a tyre depends on the output of the vehicle compressor at the time, the internal volume of the tyre and pressure change to be made. Of these 3 variables, the compressor output is perhaps the most significant as this will determine the rate of air flow to the tyres. The Scania 4 Series truck used for the Highland trial was equipped with a Knorr-Bremse AG 600cc two cylinder reciprocating air compressor, capable of producing a maximum delivery of 800 litres/min of air at 2000 rpm. This maximum delivery of air however was only possible at maximum engine revolutions on "full thottle", an unusual circumstance in reasonable vehicle operation. Similarly attempting to inflate tyres at idling speed with very low engine revolutions would be excessively long. It was therefore decided to check the inflation time at the normal 'economy' operating level of the test vehicle, ie 1200-1600rpm for the Scania 4 Series.

A 'theoretical' time for inflation for a change in pressure of 20 psi (138 kPa) was calculated using the mid economy engine speed of 1400 rpm, less 10% efficiency for the elderly Scania engine, producing an air flow of 500 l/min on a straight proportional basis. The resulting inflation time for tyres was calculated using the formula:

Time = (Tyre Volume (l) / Compressor Output (l/min)) x change in atmospheres

When this equation was applied to the 20 tyres of the TPCS test vehicle it was calculated that it would take approximately 5.9 minutes to raise the tyre inflation by 20 psi (138 Kpa) as detailed in Table 3.3.

Table 4.6 Knorr-Bremse AG 600cc compressor, economy output 500 litres/min @ 1400 revs less 10%

Axle	Tyres	Volume (litres)	No of tyres	+ 20psi (138 kPa) (minutes)	+ 40psi (276 kPa) (minutes)
Steer	295/80 R XDY	127	2		
Drive	295/80 R XDY	127	4	1.4	2.8
TAG	385/65 R XTE2	172	2	0.9	1.9
Trailer	11 R 22.5 XTE2	110	12	3.6	7.2
Totals		**536**	**20**	**5.9**	**11.8**

This calculated inflation figure of 5.9 minutes was compared with the driver's perception of the normal 'operational' inflation time for raising the pressure in the tyres from 55 psi (379 kPa) to 75 psi (517 kPa). This change was carried out as the loaded test vehicle approached Kinbrace and it was the driver's view that the inflation took approximately 6 km to take effect provided that there were no other demands on the compressor such as from the brakes or clutch.. During this time the vehicle would be normally travelling at around 60kph with the engine running within the 'economy' range. This distance at 60 kph equates to 6 minutes, the same as the calculated figure.

This time however does not correspond with the inflation time indicated by the TIREBOSS system in the vehicle cab. The TIREBOSS system carries out a series of safety checks inside the system before the computer signals that the inflation pressure has been successfully reached in all tyres. Air brake pressure reserves take priority over tyre inflation at all times.

4.7 TPCS RELIABILITY

The TIREBOSS system used on the test vehicle was a "TPC-TBM210 Truck and Trailer Control 2 valve system". Labour costs for repairs over the trial period of 13 months were of the order of 400 €, the minor parts involved being supplied free by the manufacturer. Assuming that the parts and shipping cost 600 €, the annual repairs for the first year would be of the order of 1,000 €, or approximately 0.01 €/kilometre travelled. This compares favourably with reports of levels of utilisation 95.5%, or an average of 0.02€/km, reported in trials in Sweden. (Granlund) GA Mackenzie confirmed that the system had performed well in it first year but considered that repair costs would rise, as with any other electro-mechanical object, as the equipment got older.

4.8 FUEL CONSUMPTION

Fuel consumption was not accurately metered in the Highland trial as facilities were not available to do so. The perception of the owner/operator of the Highland test vehicle was that that the test vehicle equipped with TPCS had the same fuel consumption, or slightly more, than the test vehicle before the trial. This was not the experience however of the 2 TPCS vehicles operated by James Jones and Sons Ltd. Their analysis of their fuel consumption records "before" and "after" the installation of TPCS revealed a slight improvement (0.5%) in fuel consumption on their 6x2 vehicle and a measurable improvement (4%) in their 6x4.

Table 4.7 Perceptions on the effects of fitting TPCS on fuel consumption

Fuel consumption	**Comment**
No appreciable change	*GM: Agreed. Probably little change but difficult to assess accurately as consumption varies from location to location.* *JJ: We have carried out a fuel analyses after 4 months and we detect a marginal improvement in fuel consumption. Around 4% for a double drive vehicle and 0.5% for a 6x2. The "before" and "after" cases were slightly different in types of operation but we think that the figures are reasonably robust.*

There is however an argument advanced by Granlund (2007) that says, even with no visible fuel consumption improvement, fuel consumption/m³ of timber transported can actually improve vehicles can carry heavier payloads on restricted roads with a poor bearing capacity.

4.9 IMPACT ON ROADS TRAVELLED

This report did not set out to records the effects of the Highland trial on the public roads concerned. This matter is address in the companion report to this report "Developing and applying a basic understanding of low volume pavement behaviour" by Dawson et al. Some general perceptions were however invited from The Highland Council, the public road authority for the B871 and A897 public roads, and Forestry Commission Scotland, the forest authority for the public forests at Syre, and these are given below. There is no data to support the various statements made but the perceptions offered are positive about the effects of TPCS. The Highland Council and Forestry Commission Scotland are Scottish Partners in the ROADEX III Project.

Table 4.8 Perceptions on the effects on the public road from The Highland Council

Effects on road	**Statement from The Highland Council**
Decreased road damage and longer road life?	*The trial has been ongoing for a relatively short period of time so it is difficult to draw firm conclusions. However on visual inspection there has been little deterioration in the condition of the single track network used in the trial. Any reduction in damage may be partly due to the trial vehicles being closely monitored in terms of speed and tyre pressure. In addition the frequency and intensity of heavy vehicle traffic is about half of what was extracted in previous years.*
Decreased road maintenance and associated maintenance costs?	*Since the start of the TPCS trials last year on the B871 and A897 the Council have not contributed any funding towards the maintenance of the two roads. It has not been necessary to react to problem areas as no damage has been reported. In previous years the B871 was a patched on a weekly basis.*

Table 4.9 Perceptions on the effects on the forest road from Forestry Commission Scotland

Effects on road	Statement from Forestry Commission Scotland
Decreased road damage and longer road life?	*Ran over several Class A forest roads and a Class C forest road. The Class C would usually have required significant strengthening ahead of timber extraction. This strengthening work was not required*
Decreased road maintenance and associated maintenance costs?	*No maintenance was required on these roads. In normal operations FCS would have expected to regrade and patch the roads on demand on a regular basis. This was not necessary.*
Reduced use of aggregate in road construction and maintenance?	*Yes. This has been proved by the use of the Class C road at Dalharrold with no preparatory works.*
Rutting and washboarding can be healed?	*Yes, rutting caused by forwarders coming on to the forest roads has been healed. Washboarding is experienced with intensive use of the road by heavy vehicles. Only vehicles with TPCS were used in the Syre/Dalharrold area.*

Table 4.9 Perceptions on the effects on the forest road from James Jones & Sons Ltd

Effects on road	Statement from James Jones & Sons Ltd
Decreased road damage and longer road life?	*JR: Operationally we have found that soft forest roads can hold up fairly well where the TPCS trucks can work alone and can create a packed crust on the surface.* *Where the roads are new and quite weak, we have found that mixing high and low tyre pressure traffic doesn't work well. The high tyre pressure trucks tend to cut through the crust created by the TPCS traffic and wreck the road surface causing everyone to get stuck. We therefore do not mix traffic on weak forest roads.*

Chapter 5. Discussion

5.1 GENERAL

The main aim of the Highland TPCS trial was to test the potential benefits of tyre pressure control systems to timber extraction vehicles on the minor rural road networks f the Scottish Highlands. A number of issues have been addressed during the trial, some by records and some by general perceptions. The brief for the trial was to

1. To introduce TPCS to the Scottish forestry industry, and to the Scottish Highlands in particular; and
2. To trial the performance and reliability of the TIREBOSS system.

These aims have been achieved, in part at least. TPCS, and TIREBOSS, have been successfully introduced into the Highland area and are now well known throughout the Scottish timber haulage industry. A measure of their success is that they are a regular topic of conversation when timber haulage contractors and drivers meet.

The trial has been conducted over a timeframe of 13 months, involving a distance of some 117,000 km of timber haulage with the test vehicle, carrying approximately 9,000 tonnes of timber. Unfortunately, like all short-term research projects not enough information has been gathered at this time to answer all of the questions that have arisen. Further research is required before definitive conclusions can be reached on the longer term benefits of TPCS.

What can be said clearly however at this stage is that TPCS looks a promising technology for heavy haulage vehicles with a mixture of ‘on’ and ‘off’ road operations, and that it will have a significant effect on the Scottish timber haulage fleet over time.

5.1 GENERAL PERCEPTIONS

A number of perceptions have been recorded during the trial. Contractors using vehicles fitted with TPCS are beginning to recognise the operational efficiencies that the use of TPCS can bring. They state that they are now more confident when they despatch a vehicle to a problematic site that it will get to the timber stockpile, pick up the load, and get out again, without it getting into difficulties or needing recovery. Comments from these companies are very positive, particularly in the greater range of operations and sites that can be tackled by vehicles with TPCS.

Interestingly, it is those companies who already have TPCS vehicles that are purchasing more TPCS units in an effort to keep their competitive advantage and stay ahead of their competitors. This is a key development and one which recognises the potential of the new system to make commercial profits for haulage companies.

5.2 COSTS

Vehicle costs

The cost of the TIREBOSS system fitted to the Highland trial vehicle was 15,000 €. This is estimated to offer a payback period of 4.8 years, with a marginally negative ‘Internal Rate of

Return', using the TIREBOSS spreadsheet. The calculation however is a very conservative estimate for the particular circumstances of the Scania 164L 6x2 tractor unit, 25/26 tonne payload, tri-axle, twin tyred trailer used in the trials. A number of significant potential benefits were removed from the calculation as they were unproven during the trial, eg fuel consumption, re-use of tyre casings, etc. Other cost scenarios that could be considered include:

a) The re-use of the TIREBOSS retro-fit kit on further vehicles. In this case the second use, and subsequent uses, would only incur the transfer costs of the kit, approximately 4,000€ rather than the cost of new installation at 15,000 €. This would result in a payback period of 1.4 years and an 'Internal Rate of Return' of 38%.

b) Using 'wide-single' trailer tyres as Section 4.2, Figure 4.2. A 6x4 double drive vehicle combination with 'wide-single' trailer tyres was estimated to have a capital cost payback of 2.9 years, IRR of 11% and a 6x2 TAG single drive combination a payback period of 3.1 years, IRR of 9%. Standard 'wide single' trailers are currently restricted in timber haulage operations on the majority of minor Scottish public roads.

c) A further possible option for the future could be the use of a 6x2 tractor unit equipped with TPCS as a replacement for the traditional 6x4 double drive tractor unit. This possibility gives rise to some interesting considerations in the UK context. Assuming a common manufacturer (eg Scania, Volvo, DAF, etc), a 6x2 vehicle is generally lighter, uses less fuel and can carry a higher payload that the equivalent 6x4 vehicle. These differences are summarized in Table 5.1 below. If this scenario can be considered, the payback period can be less than a year when the reduced fuel consumption is taken into account, and this calculation does not include the benefits to tyres, traction and payload.

Table 5.1 Comparison of 6x4 double drive tractor unit and a 6x2 tractor unit with TPCS

	6x4 Vehicle	6x2 vehicle with TAG and TPCS	Benefit
Price			7000 €
Tractor weight	10 tonnes	9 tonnes	1 tonne/journey
Payload	25 tonnes	26 tonnes	+1 tonne/journey
Fuel consumption	0.62 litres/km	0.54 litres/km	8000 €/year

This 6x4/6x2 scenario would require to be operationally tested on all likely road surfaces, gradients and alignments, using both loaded and unloaded vehicles before procurement and safety policies could be developed, but published material from Canada and Sweden indicates that sufficient traction increase can probably be generated by low pressure TPCS to make the idea possible. A comparative trial between a 6x4 vehicle and a 6x2 vehicle with TPCS, including drawbar tests, could be a first step to check this.

Reduced vibration can also affect the running costs of the vehicle. The perceived reduction in vibration by drivers and owners should result in less wear and tear on the vehicle, resulting in lower costs for servicing and repairs. This in turn may permit the vehicle to retain a higher value at resale than would otherwise have been the case. The Scottish hauliers using vehicles equipped with TPCS are already considering extending the working life of their vehicle from 5 to 6 years as a result of the perceived reduced vibration.

An interesting cost benefit is reported by Granlund (2006). In long term TPCS trials conducted by Skogforsk on Swedish roads it was calculated that fuel consumption marginally rose (less than 1% per tonne-kilometre) with vehicles equipped with TPCS, but given that the vehicle could carry a heavier payload on roads with a low bearing capacity, the fuel consumption, expressed in terms of unit tonne of timber transported, actually fell.

Road owner costs

Cost is also a concern to the forest owner. Currently the construction of a new forest road in Scotland can cost of the order of 2.50 Euros per tonne of timber harvested, and even further maintenance costs to keep it in a serviceable condition. If road standards can be lowered, and road construction costs reduced, this should have an effect on the delivered cost of wood at the processing factory. Initially these savings will probably be a benefit solely to the selling agents, as their forest roads could be constructed and maintained to a lower standard for TPCS vehicles. In time however, once established, these savings should be shared. Access roads would not have to upgraded ahead of harvesting making marginal forest blocks better commercial opportunities.

5.3 VEHICLE PERFORMANCE

The section on vehicle performance must by necessity deal with the reduction, or absence, of adverse records supplemented by personal perceptions from practitioners. These ‘records’, or the absence of records, from the Highland trial however bear out information already available from similar trials in Canada and Sweden, namely, that TPCS trials confirm:

- no bogged vehicles;
- no recoveries;
- less wheelspin;
- reduced vibration levels;
- vehicles being sent to locations not possible before.

It was noted in the Scottish Highlands that drivers of 6x2 vehicles without TPCS had the practice of lifting the TAG axle on difficult sections of forest roads to try to improve traction. This practice adds load to the other axles of the vehicle, and particularly overloads the drive axle, which can result in damage to the road. Forestry Commission Scotland (FCS) has reservations about this practice and considers it unsafe. FCS believes that it would not be necessary with TPCS equipped vehicles as the emergency setting of 35 psi (241 kPa) would increase the tyre footprint sufficiently to increase traction and, more importantly, keep all axles on the road reducing stresses. This TPCS benefit was demonstrated during a private test at Eskdalemuir in March 2007. The Highland test vehicle was requested to stop on a steep gradient that had been giving problems to other vehicles. The driver did this and then drove away at 35 psi (241 kPa) with the TAG axle down.

It has not been possible unfortunately, in the limited time of the Highland trial, to compare the relative performances of a ‘6x2 TPCS vehicle with a TAG axle’ against a ‘standard 6x4 double drive' option, as mentioned in 5.2(c) above. Contractors who have used TPCS during the trial period believe however that the two performances may be similar, with the added benefit of the 6x2 vehicle being more manoeuvrable on the road. A comparative trial of the traction capabilities of a standard 6x4 vehicle and '6x2 with TPCS' would be a useful trial to establish their relative performances (as the drawbar pull tests reported by Bradley 1993).

TPCS was not fitted to the steer axle of the Highland test vehicle, and has not been fitted to any of the other four vehicles currently equipped with TIREBOSS in Scotland. FCS had reservations about the handling characteristics of TPCS at the time of purchase and, as the system was new for Scotland, it was agreed to omit fitting TPCS to the front axle. The additional cost for fitting TCS to the steer axle has been quoted at approximately 5,000 € per vehicle.

A first step of trialling TPCS for new users, without opting for a full purchase of a trial system, could be a manual reduction of tyre pressures down to 75 psi (517 kPa) on the tyres of an existing vehicle, with an appropriate reduction in road speed so as to be in accordance with suggested pressure matrix by Michelin UK. This "constant reduced pressure" trial could give an indication of the potential benefits of TPCS, of increased contact area and traction, without the outlay of money and with minimum time.

5.4 TYRE PERFORMANCE

Tyre performance results from the trial have been very positive, and hard measurement data has been obtained. In summary, these include:

- Extended tyre life, with even tread wear and "dramatically lowered damage";
- Less tyre changes needed;
- Even tread wear across twin tyre assemblies;
- One puncture – by a nail;
- No blowouts;
- 30% increase in life of drive tyres
- Tyres capable of being re-grooved for first time
- Potential for Michelin "4 lives" tyre management

This data confirms the reported improvement in tyre performance from Canada and Swedish trials. Perhaps the most notable improvement in tyre performance was the recorded increase in performance of the drive tyres of the test vehicle. The owner of the Highland trial vehicle normally expected his drive tyres to last 50,000 - 60,000 km in the past. His vehicles were regularly sent into sites where wheel spin of the drive tyres was common and this had a significant effect on the usable life of the tyres. With TPCS fitted, wheel spin on the drive tyres was reduced and their usable life was extended to 79,000 km, an increase of 32% over the previous maximum expectation. This distance travelled was subsequently extended to 108,500 km after regrooving by Michelin UK, equating to an improvement of 81% over the previous maximum life, with an expectation of a further 10,000 km with similar usage.

On the more general issue of good tyre management, two measures were suggested during discussions with Michelin UK:

1) The use of slightly larger tyres on the steer and drive would permit lower tyre pressures for the same load and would slightly increase ground clearance, a feature particularly useful on forest haul roads. It was suggested that future trials could try 315/80 R 22.5 tyres instead of the 295/80 R 22.5 tyres used in the current Highland trial. The 315/80 R 22.5 tyre is slightly more expensive but should return a proportionally higher distance travelled. A wider tyre on the steer axle was also suggested by Mr Brian Spreen, President of Tire Pressure Control International Ltd, in a personal conversation with the authors at the ROADEX final seminar in Inverness on 9 November 2007.

2) Regrooving of tyres is suggested to be effective practice that can aid the fuel efficiency of a tyre as shown in Figure 5.1 below. The "New XDY drive tyre" schematic on the left indicates how the fuel efficiency of a typical tyre increases as the tread depth reduces with wear. Regrooving such a tyre takes place in the "high kpl" (kilometres per litre) and extends the benefits that accrue with a low tread depth.

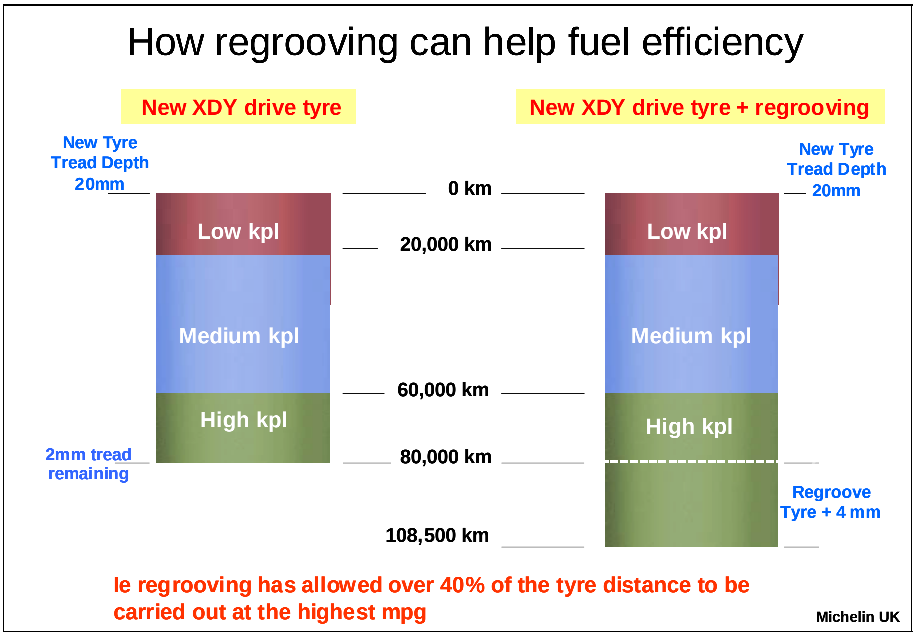


Figure 5.1 Diagram showing how regrooving of a tyre can help fuel efficiency

5.5 PERCEPTIONS OF OPERATORS

The general perceptions of the operators involved in the trial were equally positive. Drivers reported a smoother vehicle ride an improved comfort in the cab with TPCS. Owners and managers were optimistic about the benefits to vehicles through reduced vibration and extended vehicle life.

Health and safety issues were are a concern for both drivers and managers. All felt that the improved traction, less wheel spin, fewer tyre changes and reduced vehicle recovery incidents were positive contributions to improved health and safety. Accidents were more likely to happen in timber operations when the driver was out of the safety of the cab and

TPCS was seen to have positive benefits in reducing the need for the driver to dismount from the vehicle.

5.6 TPCS RELIABILITY

The TIREBOSS system used in the trial was trouble free for the duration of the trial over 117,000 km. Some initial modifications were required at the TIREBOSS initial set up but once operational the system required only maintenance greasing.

5.8 FUEL CONSUMPTION

It was not possible to accurately measure fuel consumption on the Highland test vehicle due to the limited facilities at the operational base in Kinbrace but the perception of the owner of the trial vehicle was that here was little difference from the previous performance.

Fuel monitoring was however carried out by James Jones and Sons Ltd on their two vehicles equipped with TPCS over the period June to October 2007. Fuel records over this short period indicated that fuel consumption had improved by 0.5 % for the 6x2 TAG vehicle and by 4 % for the 6x4 double drive vehicle. These figures were based on comparison with performance records of similar vehicles in the past.

5.9 IMPACT ON ROADS TRAVELLED

Both the Highland Council and Forestry Commission Scotland reported reduced maintenance needs on the minor roads used by the TPCS vehicle. The B871 and A897 public roads did not require any reactive maintenance over the 13 months of the trial. Similarly the forest haul roads into the Syre forest blocks did not require improvement for haulage traffic as would have been the case in the past with non-TPCS vehicles.

A caveat this was that TPCS traffic should not be mixed with non-TPCS traffic on weak forest roads as any benefits of TPCS on the road would be lost.

Chapter 6. Conclusions

A short term trial of a system of tyre pressure control has been carried out on a timber haulage vehicle in northern Scotland and a number of perceived benefits of TPCS have been recorded. These benefits lead the author to believe that there is a place for TPCS in timber haulage operations, particularly where there is a significant proportion of the haulage route on weak or forest roads. The decision on whether to purchase TPCS for a vehicle will be made on the basis of “cost v perceived benefits” and initially, for the pioneer contractors at least, the decision to fit, or not to fit, will probably be based on a leap of faith rather than operational data gathered by others There are however significant published papers on results and experiences gathered overseas, most notably in Canada and Sweden, that can support the fitting of TPCS to at least some vehicles in the timber haulage fleets of the ROADEX Partner countries.

This is happening in small numbers at present. At the date of writing the report in early February 2008, there are 22 vehicles equipped with TPCS in Sweden, 5 vehicles in Scotland and one being planned in Finland. The 5 vehicles equipped in Scotland over 2006-07 can be considered to be direct consequences of the FCS-ROADEX trial and this has to be seen as a significant commercial confirmation of the positive experiences gained.

The following conclusions can be drawn from the Highland trial.

1. Tyre Pressure Control is a promising technology for heavy haulage vehicles with a mixture of ‘on’ and ‘off’ road activities;
2. Short term benefits have been identified over the course of the 13 month trial in respect of tyre life, tyre management, vehicle traction, vehicle mobility and extended hauling seasons, confirming the results of similar trials in Canada and Sweden;
3. A longer period of trial is required to fully assess the system.

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APPENDICES

A A Brief History of Variable Tyre Pressure

B British Columbia Ministry of Transportation Tire Pressure Control Systems Use During Seasonal Load Restriction Period

C Swedish Policy

D Accreditation of TPCS Equipped Vehicles In Sweden

E Michelin Tyre Pressure Recommendations

F “TIREBOSS” Spreadsheet

Appendix A

A BRIEF HISTORY OF VARIABLE TYRE PRESSURE

The following brief history of variable tyre pressure technology was prepared by Allan Bradley of FPInnovations FERIC-Division, and reviewed by Brian Spreen of TPC International Ltd and Ed Gililland of the US Forest Service San Dimas Technology & Development Center.

A Brief History of Variable Tyre Pressure

Variable tyre pressure technology is not new. The following brief history of variable tyre pressure technology was prepared by Allan Bradley of FPInnovations FERIC-Division, and reviewed by Brian Spreen of TPC International Ltd and Ed Gililland of the US Forest Service San Dimas Technology & Development Center.

1) Central Tyre Inflation System (CTIS)

1940 – 1947

General Motors developed the first CTIS vehicle, the 2.5-ton 6x6 DUKW 353 amphibious landing craft, for WWII. This vehicle had a pantograph central tyre inflation system (externally plumbed lines to each tyre controlled by a regulator and fed by an electric compressor). The “Duck” was a very successful vehicle, especially during the invasion of Italy in 1943-44. CTISs were also developed for larger amphibious vehicles, such as the 15-Ton Goer “Super Duck”, the Drake, and the Larc 60 (60 Ton).

The technology was distributed to allies through the “Lend-Lease” program and the USSR started mass producing trucks based on the Studebaker truck design and CTIS at the large ZIL truck plant south of Moscow.

1947 – 1960s

The USA began developing a 5-ton advanced technology army truck that included an automatic transmission and CTIS. The automatic transmissions had lots of problems with reliability. The GMC T51 prototype had an external pantograph CTIS (later considered too vulnerable for military applications) and the Mack T54 prototype had internally plumbed slip rings for the transmission of air. The advanced army truck program was shelved in 1952 because of the need for off-the-shelf technology for use in the Korean war, (ie the WWII trucks already held in store).

The USSR continued to develop CTIS in the following years and were the first to put CTIS on a mass produced military truck in 1958. This was the 2.5-Ton 6x6 ZIL-157. Prior to this they installed CTIS on an amphibious vehicle (BAV 485 using US CTIS with some slight Soviet upgrades) and on an armoured personnel carrier (BTR 152V1). The armoured personnel carrier was a new application at the time.

The USSR also pioneered tyre designs for use with CTIS. These consisted of single tyres with tread wrapped up the sidewalls and high traction designs. Sidewall stiffness was carefully controlled so the tyre would develop large footprints, wouldn’t collapse at low pressures, and could be used with run-flat devices.

1960 – 1970s

The USSR continued to refine CTIS and CTIS applications during the 60s and 70s. CTIS was installed on a wide variety of tactical wheeled vehicles. By 1960, all of the USSR tactical wheeled fleet was equipped with CTIS except for two models: a jeep that was considered too small for CTIS and a tanker truck that used high pressure/ high capacity tyres that couldn't be deflated. By 1970, most of the Soviet Bloc's tactical wheeled fleets had CTIS incorporated.

1970 – 1990s

In the early 1970s, the US wished to sell military equipment to Egypt but were told that they must have CTIS. This revived interest in CTIS on US military vehicles and systems were developed by companies like AM General, Oshkosh, Rockwell, and Eaton. In 1979, the need to develop off-road mobility in Iran spurred further interest.

During the 1980s, the Soviet Union added forestry, oil field, agriculture, semi-trailers and exploration trucks to the list of ground vehicle CTIS vehicles. They also installed CTIS on aircraft, especially military transport planes in an effort to reduce remote landing strip requirements.

In early 1990s, the US army let a contract to Stewart & Stevenson to produce the new Family of Medium Tactical Vehicles (FMTV) – most of which were to be equipped with Eaton CTIS. The design of the Eaton CTIS today is relatively unchanged from the design developed in the 1980s. In the early 1990s there were approximately 33 CTI systems in use by militaries worldwide.

Further details on CTIS development can be found in Rob Warner's SAE Paper 942335 "Central Tire Inflation Systems (CTIS) Technology, Development, and Application".

2) Tyre Pressure Control Systems (TPCS)

1980 - 1991

Parallel to the above military development of CTIS there was also the development of CTIS for commercial vehicles that ultimately led to the development of TPCS. In the early 1980s, Stanford University installed a CTIS on a log truck to prove the concept. The USDA Forest Service San Dimas Equipment Development Center pioneered the implementation of CTIS on log and gravel hauling trucks, with systems operating in Oregon, Washington, California, Alaska, Michigan, Alabama, and Oklahoma (in cooperation with Weyerhaeuser Corporation.). This initiated about 25 years of research by the USDA Forest Service (USFS) on the technology and their projects looked at both truck and road benefits (especially road benefits); cooperative studies also were done with tyre companies to look at tyre benefits. Numerous reports document both controlled studies of road, tyre and truck effects (by Nevada Automotive Test Center and the US Army Corps of Engineers) and operational trials in national forests.

Implementation efforts by the USFS were ultimately unsuccessful for a variety of reasons, including: their contractual relationship with timber harvesters who subcontract the truck owners prevented the USFS from directly compensating truckers for the purchase of CTIS; tyre companies were calling for more testing before endorsing VTP and they published an interim VTP standard in 1987 for use in testing; the US timber industry was goiung through difficult times and this new technology was seen as risky; and, perhaps most importantly, the CTIS and airing stations were still prototypes and not reliable.

Refer to Ed Gililland's Paper for the 1989 Akron Rubber Group Winter Tire Symposium Trucks, Tires and Roads: Forging a Partnership for a detailed summary on CTIS research by the USFS in the 1980s. Copies of the various USFS-sponsored research reports are available from the USFS San Dimas Technology & Development Center, Nevada Automotive Test Center, and the Waterways Experiment Station - US Army Corps of Engineers.

In 1988, FERIC installed an Eltek CTIS on a log truck operating in BC to investigate its potential as a traction enhancing technology. The results were successful and many other benefits were noted. FERIC continued to investigate other aspects of CTIS and its ability to reduce road damage and improve mobility.

1991-1992

Eltek Inc., in partnership with FERIC, developed a prototype system for use on a 7-axle "B-train" timber truck transporting chips from an in-woods chipper. (Eltek designers were formerly with AM General designing CTIS.) The system trials were successfully conducted and documented in FERIC Technical Report TR-116 "Trial of a Central Tire Inflation System on Thawing Forest Roads" (1996).

1992-1997

In 1992, the prototype CTIS designs were given to an Athabasca-based company, Redline Equipment, who then began manufacturing, servicing, and refining the system (now called TPCS). Many of the first systems went into service in the log hauling fleet of Alberta Pacific Forest Industries (Al-Pac). This forest company mandated that its log haulers must have TPCS to haul during summer operations. At the same time Eaton Corporation also introduced a system called TPCS – many of these systems were installed on log hauling vehicles.

The implementation of TPCS was relatively slow and confined to log hauling operations in western Canada. Companies such as Alberta Pacific Forest Industries, Riverside Forest Products and Weyerhaeuser were the first to implement CTIS on a fleet-wide basis in their operations.

TPCS, in general, suffered from compressed air supply problems due to use of high flow compressors that had not been designed for the heat developed when pumping for long periods against high back pressures. Other components experienced wear or freezing problems in the challenging conditions found in northern Alberta log hauling. Air dryer manufacturers and all of the stakeholders actively sought solutions to the air supply problems in this time. Numerous small improvements were made by Redline Equipment, and their successor Tire Pressure Control International (TPC International), to improve system reliability. Eaton TPCS were more susceptible to air contamination problems and they also experienced leaking problems with drive axle seals in cold conditions. The number and cost of warranty claims eventually forced Eaton to curtail sales into the Canadian forest sector. FERIC documented the costs of operating TPCS in its Advantage Report Vol. 1 No. 30 (2000) "Ownership and operating cost analysis of log trucks equipped with CTI systems or TPCS". Ancillary comments to this report were prepared by the authors in 2004.

1996 – 2007

TPCS design changed incrementally during this period with the focus of TPC International focus being on improving component reliability, lowering system cost and weight, and developing new markets. Their latest model of TPCS is called the “TIREBOSS” TPCS. The “TIREBOSS” system can be retrofitted to all types of transport vehicles & wheel end configurations and has been proven to be very reliable, operating with minimal maintenance costs. EATON TPCS design has changed relatively little (e.g., small changes to wheel end components). In the 1990s, EATON Axle and Brake Division (including the TPCS section) was sold to DANA Corporation and is now marketed as the “ROADRANGER SPICER” TPCS. The EATON system is primarily used in military applications and is only available as a civil option on smaller configurations (fewer controlled axles) due to air supply & dryer limitations. DANA and TPC International account for almost all sales of TPCS in North America.

One notable development during this period was the linking of TPCS to on-board computers for monitoring trip data from trucks used in special haul programs. The TIREBOSS system is compatible with most on-board computers providing monitoring for compliance purposes. FERIC has been investigating this application with respect to hauling on seasonally load restricted pavements, and has published internal reports and conference papers on several of the trials carried out to-date.

The US Tire & Rim Association published its CTIS/ TPCS load inflation table as a standard in 1999 (it was originally published in 1989 as an interim standard for USFS testing). At the request of FERIC, the T&RA also published a load-inflation standard for CTIS/ TPCS use at 80 km/h max. In 2006, Michelin announced that it endorsed the use of CTIS/ TPCS and would honour warranty on tyres operated with these systems. In general, tyre companies have been honouring warranty on tyres run at variable tyre pressures on a case-by-case basis, and all require that the pressures used match T&RA recommendations. These developments reflect the growing acceptance of VTP by tyre manufacturers.

New markets have been developed by both TPC International and DANA Corporation and this has allowed growth in sales and supported the companies during slow periods in forestry. TPCS are now sold for agriculture, quarry, bulk transport, fire fighting, transit mixer (cement mixer), oil field and exploration vehicles. TPCS are sold in countries around the world including New Zealand and Australia, China, as well as in South America, Europe, Africa and the Middle East.

Further information on TIREBOSS TPCS can be obtained from TPC International www.TIREBOSS.com. Information on ROADRANGER SPICER TPCS can be found at http://www.roadranger.com/Roadranger/productssolutions/tiremanagement/index.htm.

Appendix B

CHANGES IN CANADIAN HAULAGE REGULATIONS AS A RESULT OF TPCS

British Columbia
Ministry of Transportation

Tire Pressure Control Systems

Use During Seasonal Load Restriction Period

Technical Circular T – 11/04

September 30, 2004

2004 trial TPCS sign for Pope & Talbot Ltd
and used on roads near Midway, BC

Technical Circular T – 11/04
Date: September 30, 2004

To: **District Managers, Transportation**
Director, Construction and Maintenance Branch
Director, Engineering Branch
Engineering Branch Section Heads
Regional Managers of Engineering
Regional Managers, Operations
Regional Geotechnical and Materials Engineers
Manager, Engineering and Real Estate Operations, MoF
Director, Commercial Vehicle Safety and Enforcement, MPSSG

Subject: **Tire Pressure Control Systems**
Use During Seasonal Load Restriction Period

Objective:

The Ministry of Transportation (MoT) will now allow exemptions to the Seasonal Load Restrictions Program when Tire Pressure Control System (TPCS) technology is used.

Background:

Seasonal Load Restrictions, restricting the legal loads carried by trucks, are placed on many roads used by industry during the spring. The load restrictions are intended to prevent excess damage to the roads during a time when the roads are weakened and the restrictions can be in place from 6 to 8 weeks or even longer. With these restrictions in place, it can become uneconomic for industries to use the roads.

The Seasonal Load Restrictions are put in place by use of frost probe data, historical beam reading data and weather data for the current year. Typically, the timing for the removal of load restrictions is based on regional beam data but also on historical data and visual observations. It has been shown that with the use of reduced tire pressures with TPCS, there is no increase in damage to the road during the later portion of the Seasonal Load Restriction period. Trucks can therefore start hauling at an earlier date during this period on selected roads.

TPCS allows truckers to automatically reduce and increase tire pressures to pre-set optimum levels over the course of a trip by use of an onboard computer. A data logger installed in the truck records tire pressures and vehicle speeds during the trip and this information will be downloaded. This information along with vehicle axle weights, will be monitored by government staff to ensure compliance with the regulations and to ensure safety.

The benefits to the truck based industries and to the Provincial economy include the following:

- more efficient use of trucks,
- traffic congestion at times will be reduced,
- inventory carrying costs and land use costs are reduced,
- multiple log handling in yards is reduced
- the yield and value of wood is increased due to the hauling of fresh logs during this period
- extended employment season for workers
- highway infrastructure degradation is reduced if Tire Pressure Control systems are used outside the Seasonal Load Restriction period.

It is intended that, with this technology, the government will ensure that the resource roads are not significantly damaged by inappropriate use during the spring thaw.

Details of the TPCS program:

Individual firms (i.e. forestry companies, trucking companies, mining companies, oil and gas industry, fuel hauling companies, etc.) would make formal application to MoT District offices for inclusion of specific roads and trucks into the program. Individual MoT Districts would then review the application for suitability and issue the exemption letter of authorization. Enforcement of the exemption would be the jurisdiction of Ministry of Public Safety and Solicitor General. This would done by accessing data loggers installed in each truck with information made available for viewing. Hauling on specified roads would commence when road strength has reached permitted values. See attached flow chart of process.

Application to MoT would need to include the following details:

- List of proposed roads and posted speeds
- Firm making application and contact information (address, phone and fax numbers, email)
- Beam Consultant registered in MoT Registration Identification Selection and Performance Evaluation System (RISP)
- Truck Company Name and contact information
- Truck and trailer configuration. A list of typical truck configurations is provided for information in Attachment 3. This list is not a list of acceptable configurations but only provides configurations for discussion, terminology and identification.
- Truck and trailer vehicle Identification number
- Truck and trailer plate numbers
- Number of proposed daily loads and days of hauling

- Precondition survey data (loaded and unloaded lanes):
  1. Beaming of key road segments at peak strength (early fall) (one 1000m long control section per proposed road segment, one beam reading per 100 m, control section placed at the weakest point within the road)
  2. Video of proposed segment taken as driving along the road segment and under good lighting at a speed of less than 50km/h

This policy does not permit the use of single axle rear jeeps. It should also be noted that all single non steer axles are restricted to axle weights of 8,000 kg. Also, this policy does not affect tire pressures for steer tires. Applicable tolerances are not included in determination of vehicle axle weights.

District will review the roads for suitability considering the age, condition, structural make up of the road and other traffic loading. Some roads may be excluded as they are deemed to be at very high risk of deterioration. Roads to be excluded from the program will be those that have peak fall strength reading above 1.5mm.

The Letter of Authorization to the applicant is to be reviewed by Manager of Commercial Transport, Ministry of Public Safety and Solicitor General.

When issuing the approval, the District will specify the following:

- List of roads for which the approval applies,
- List of acceptable trucks, configurations (TABLE)
- Required tire pressures will be 55 psi for travel speeds of 50km/h and 65 psi for travel speeds of 80 km/h. The Ministry District offices will review travel speeds as provided in the Industry applications according to the posted speed limits and the road alignment challenges.
- Threshold rebound value (as proven by the Benkleman Beam testing) will be 1.5mm before hauling can commence (i.e. trucks may still be prohibited from hauling during the very weakest road strength conditions).
- Required TPCS truck equipment shall include data loggers to permit enforcement audits. Data loggers must collect and collate the following data for that portion of the route that is load restricted:
  - trip route,
  - TPCS-controlled tire pressures, and
  - truck speeds.

  Data must be collected at a frequency that allows enforcement for any point along the route.
- Axle weights for each trip must be added by the applicant to the trip data and posted on the web site.
- Benkleman Beam data collection requirements – the applicant is responsible for beaming of the road to determine when the rebound value reaches the required threshold value at which time hauling can begin. Beaming must be carried out at the same location as the early fall test section where the maximum strength was determined.
- Signage on approved TPCS road shall be erected before start of hauling.

Applications must be submitted by no later than October 15 for the following road strength loss season.

Penalties

Penalties for failing to follow the terms of the exemption as determined by audits of the data logs would be incremental:

1. First offence – written warning to trucker and applicant firm
2. Second offence – exemption voided for remainder of load restriction season to trucker and written warning to applicant firm
3. Third offence - a three year moratorium would be placed on that trucking company and/or the division of the applicant firm for application to the program anywhere in the province

Ministry reserves the right to immediately revoke permissions for individual truckers and/or the trucking company for gross violations without proceeding through the intervention process described above.

Additional Conditions:

1. MoT retains the right to revoke the exemption at any time without notice during the TPCS Haul Program.

Contact:
Mike Oliver, P. Eng.
Chief, Geotechnical, Materials and Pavement Engineer
Engineering Branch

Mike Oliver for
Dirk Nyland, P. Eng.
Chief Engineer

Attachments

1. Sample Letter of Authorization
2. Application Form
3. Truck configurations
4. General Benkelman Beaming Guidelines in Support of Tire Pressure Control Systems
5. Flow Chart of application and approval process
6 Standard TPCS Haul Route signage

Appendix C

CHANGES IN SWEDISH REGULATION AS A RESULT OF TPCS

Swedish Policy

Figure C1 Temporary road sign on Road no S926 in Värmland, Sweden
The lower plate of the sign says "Does not apply to the CTI project"

Vägverkets författningssamling

VVFS 2007:3

Vägverkets föreskrifter om färd med fordon med variabelt däckstryck;

Utkom från trycket den 8 februari 2007

beslutade den 22 januari 2007.

Vägverket föreskriver med stöd av 4 kap. 12 § 2 stycket och 13 § 3 stycket trafikförordningen (1998:1276) följande.

Inledande bestämmelser

1 § Dessa föreskrifter innehåller bestämmelser om färd med ett fordon eller ett fordonståg på en väg som tillhör bärighetsklass 2 eller 3 trots att de värden som anges i 4 kap. 12 § första stycket trafikförordningen (1998:1276) överskrids eller trots att de värden som anges i 4 kap. 13 § första stycket trafikförordningen underskrids.

2 § De beteckningar som används i dessa föreskrifter har samma betydelse som i lagen (2001:559) om vägtrafikdefinitioner och förordningen (2001:651) om vägtrafikdefinitioner.

3 § Om de villkor som anges i 4 - 8 § uppfylls får fordon och fordonståg framföras på de vägar som anges i bilagan, trots att de värden som anges för bärighetsklass 2 eller 3 i 4 kap. 12 § första stycket trafikförordningen (1998:1276) överskrids eller de värden som anges för bärighetsklasser 2 eller 3 i 4 kap. 13 § första stycket trafikförordningen underskrids. De värden som anges för bärighetsklass 1 i 4 kap. 12 § första stycket trafikförordningen får inte överskridas och de värden som anges för bärighetsklass 1 i 4 kap. 13 § första stycket får inte underskridas.

Villkor

4 § Fordonen skall ha utrustning för central reglering av däckstryck på alla hjul, CTI.

5 § Andra axlar än ett motorfordons framaxel eller framaxlar skall vara försedda med dubbelmonterade hjul.

6 § Fordonen får inte ha högre däckstryck än

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600 kilopascal i däck på ett motorfordons framaxel, eller framaxlar,
400 kilopascal i däck på annan axel på ett motorfordon och
500 kilopascal i däck på en släpvagn

7 § Fordonen får vid färd med stöd av dessa föreskrifter inte föras med högre hastighet än 50 kilometer i timmen.

8 § Färderna skall dokumenteras beträffande
fordonens bruttovikt,
färdtidpunker,
väg och
fordonets eller fordonstågets däckstryck.

Dokumentationen skall sparas i minst tre månader och på anmodan av Vägverket överlämnas till Vägverket.

Dessa föreskrifter träder i kraft den 15 februari 2007.

LENA ERIXON

Mimmi Lundqvist Ryde

2

Appendix D

Accreditation of Vehicles Equipped with TPCS In Sweden

The following 2 pages give an example of a typical registration document for a timber haulage vehicle equipped with a tyre pressure control system in Sweden. It is understood that this vehicle can be used in any EU Member State. The line entry on page 2 “Equipped with system for controlling air pressure in tyres” records that the vehicle is equipped with TPCS.

As part of the accreditation process, the Swedish system requires the TPCS to demonstrate that:

- the system is able to deflate and inflate;
- the system permits the vehicle to brake many times, and when the pressure falls to the minimum braking pressure, the TPCS valve must close off the TPC system;
- the puncture warning system is effective. This is done by manually deflating a tyre to check that the puncture warning light illuminates.

Vägverket

Europeiska gemenskapen

S

SVERIGE

Dokumentnummer
1005294775

Del 1 av registreringsbeviset

Registreringsbevisets innehavare

C.1.2 C.1.1
C.1.3
[redacted]

Plats för brevporto

Vägverket
SE-701 81 Örebro
Sverige

C.4.a
Registreringsbevisets innehavare är ägare till fordonet

Permiso de circulación. Parte I – Osvědčení o registraci – Část I – Registreringsattest. Del I – Zulassungsbescheinigung. Teil I – Registreerimistunnistus. Osa I – Άδεια κυκλοφορίας/Πιστοποιητικό Εγγραφής. Μέρος I – Registration certificate. Part I – Certificat d'immatriculation. Partie I – Carta di circolazione. Parte I – Reģistrācijas apliecība. I. daļa – Registracijos liudijimas. I dalis – Forgalmi engedély. I. Rész – Certifikat ta' Reġistrazzjoni. L-I Parti – Kentekenbewijs. Deel I – Dowód Rejestracyjny. Część I – Certificado de matrícula. Parte I – Osvedčenie o evidencii. Časť I – Prometno dovoljenje. Del I – Rekisteröintitodistus. Osa I

Allmän information

A. Registreringsnummer: [redacted]	(A.1) Registreringsnr i sifferform: 923321962	(Z) Behörighetskod: 73256	(A.2) Personligt skyltnummer
B. Datum för första ibruktagande	(B.1) Datum för första ibruktagande i Sverige: 2005-09-30	(C.2.4) Antal ägare inklusive bilhandlare: 1	Kontrollnummer: 1758076925
(I.1) Förvärvsdatum: 2005-09-30	I. Utfärdandedatum: 2005-10-27	(Y.1) Import	
(X) Yrkesmässig trafik: Godstrafik		(Y) a) Leasing / b) Kreditköp: b) Kreditköp med förbehåll om återtaganderätt	

OBS! Medtag detta registreringsbevis i fordonet vid färd utomlands.

P-Uag011-1-2

Fordonsidentitet och kaross

A. Registreringsnummer: [redacted]	(D.4) Årsmodell: 2005	(D.18) Bredd, mm: 2550	(D.9) Lastutrymmets längd, mm	D.1 Märke: Scania/Scania-Vabis
J. Fordonskategori: Lastbil	R. Färg: Flerfärgad	(D.5) Utrustning	(D.10) Överhäng, mm	D.3 Handelsbeteckning: Scania R470lb6x4 Hha
(D.17) Längd, mm: 9950			S.1 Antal sittplatser inkl förarplatsen: 2	(D.6) Karosseri: 61 Banke
E. Identifieringsmärkning: YS2R6X40002010330		D.2 Variant		
K. Typgodkännandenummer		D.2 Version		

Vikter

G. Tjänstevikt, kg: 11220	F.1 Totalvikt, kg: 29500	(F.7) Skattevikt, kg: 26000	(F.5) Garanterat axeltryck, kg: 8500+ 21000	F.3 Högsta sammanlagda bruttovikt för bil och släp, kg: 70000
(F.6) Maxlast, kg: 18280	F.2 Högsta totalvikt för BK1-väg, kg: 26000	(F.4) Tillåten lastvikt, kg: 14780		

Motor och växellåda

P.2 Maximal nettoeffekt, kW: 345 EG	P.3 Drivmedel: Diesel
P.1 Slagvolym, ccm	(P.6) Växellåda: Manuell/Tillsats

Axlar och hjul

L. Antal axlar: 3	(D.8) Däckdimension bak: 315/80R22,5
M. Axelavstånd, mm: 4500/ 1350	(D.16) Antal hjul: 10

Miljöfakta

(V.10) Miljöklass: 2000

Kopplingsanordning

(D.11) Koppling, typ: Bygel	O.2 Högsta vikt obromsat släp, kg
(D.12) Kopplingsavstånd, mm: 8290	O.1 Högsta vikt bromsat släp, kg: 56820
(D.13) Bromsutag: Tryckluft	(D.3) Högsta totalvikt på släpet för B-körkort, kg

Övriga uppgifter (tekniska data, dispenser m.m.)

ÖVRIGA UPPGIFTER (TEKNISKA DATA, DISPENSER M.M.) SKRIVS PÅ SEPARAT PAPPER

2005-10-28 08:31:54

27535

Vägverket

Tilläggsblad
Del 1 av registreringsbeviset

Utfärdandedatum
2005-10-27

[redacted]

Registreringsnummer
[redacted]

Identifieringsmärkning
YS2R6X40002010330

Övriga uppgifter (tekniska data, dispenser m.m.)

```
T21A  DRIVAXLAR    0+2
T27A  VÄGVÄNLIG FJÄDRING PÅ DRIVAXEL
T51D  HÖGSTA VIKT FÖR SLÄPKÄRRA      24000  KG
T52E  D-VÄRDE      190    I KN.
T52F  S-VÄRDE      1000   I KG.
T52H  DC-VÄRDE     130   , V-LUFTVÄRDE     50    , V-STÅLVÄRDE     -
      I KN.
T65A  FÄSTANORDNING FÖR LASTKRAN
T65D  UTRUSTNING FÖR REGLERING AV DÄCKTRYCK (CTI-SYSTEM)
T71BC  VÄGAVGIFT I ENLIGHET MED EURO III.
4ST BANKAR
```

Equipped with system for controlling air pressure in tyres

Appendix E

MICHELIN TYRE PRESSURE SUGGESTIONS

(Dan Lamb, Technical Manager, Product Marketing Truck, Michelin UK, email 11 May 2007)

The first matrix is for a vehicle that can adjust the pressures on the three Tractor Unit axles and the Trailer separately (a four valve system). These pressures are also for a system where a pressure / temperature correction takes place. i.e. the system does not bleed pressure out of the tyres as the temperature and therefore the pressure increases.

The second matrix is for a similar system to the one above, but only using two valves. In this matrix I have used the same Steer axle pressure throughout as it is not part of the system. I have grouped the Drive and Tag pressures together, always standardising on the higher pressure. I have made separate suggestions for the trailer.

Matrix three is for a four valve system where the pressure in the tyre is the only parameter that is being measured and no correction is being made for temperature. In this type of system the pressures are maintained at the cold tyre pressure suggestion even though the tyre is heating up as it is working. For this type of system, tyre pressures must be increased by around 20% to allow for pressure being bled off.

Matrix four is for a two valve system that bleeds pressure as temperature increases. I believe that this is the system that is fitted to Gordon's vehicle.

Table 1. Cold Tyre Pressure Suggestions (For a system that corrects itself for temperature increase)

	Size	***Axle Load***	***'A' road, unladen (56mph) to Syre***	***Fully Laden in forest - gravel (25 km/h)***	***Minor public road - sealed (50 km/h)***	***'A' road, narrow & bendy (70 km/h)***	***A9 Laden 56 mph***
Axle 1	295/80	5860	75 (517)	44 (303)	100 (689)	105 (793)	115 (793)
Axle 2	295/80	9100	40 (276)	35 (241)	75 (517)	75 (517)	80 (552)
Axle 3	385/65	5100	50 (345)	32 (221)	54 (372)	70 (483)	70 (483)
Trailer	11 R 22.5	7600	60 (414)	35 (241)	54 (372)	80 (552)	80 (552)

Table 2. As Table 1, but for a vehicle that does not adjust Steer Axle tyre pressure and adjusts axles 2 and 3 to the same pressure

	Size	***Axle Load***	***'A' road, unladen (56mph) to Syre***	***Fully Laden in forest - gravel (25 km/h)***	***Minor public road - sealed (50 km/h)***	***'A' road, narrow & bendy (70 km/h)***	***A9 Laden 56 mph***
Axle 1	295/80	5860	115 (793)	115 (793)	115 (793)	115 (793)	115 (793)
Axle 2	295/80	9100	50 (345)	35 (241)	75 (517)	75 (517)	80 (552)
Axle 3	385/65	5100	50 (345)	35 (241)	75 (517)	75 (517)	80 (552)
Trailer	11 R 22.5	7600	60 (414)	35 (241)	54 (372)	80 (552)	80 (552)

Table 3. Tyre Pressure Suggestions (For a system that bleeds pressure as the temperature increases)

	Size	Axle Load	'A' road, unladen (56mph) to Syre	Fully Laden in forest - gravel (25 km/h)	Minor public road - sealed (50 km/h)	'A' road, narrow & bendy (70 km/h)	A9 Laden 56 mph
Axle 1	295/80	5860	90 (621)	50 (345)	120 (827)	125 (862)	125 (862)
Axle 2	295/80	9100	48 (331)	40 (276)	90 (621)	90 (621)	96 (662)
Axle 3	385/65	5100	60 (414)	38 (262)	65 (448)	84 (579)	84 (579)
Trailer	11 R 22.5	7600	72 (496)	42 (290)	65 (448)	96 (662)	96 (662)

Table 4. As Table 3, but for a vehicle that does not adjust Steer Axle tyre pressure and adjusts axles 2 and 3 to the same pressure

	Size	Axle Load	'A' road, unladen (56mph) to Syre	Fully Laden in forest - gravel (25 km/h)	Minor public road - sealed (50 km/h)	'A' road, narrow & bendy (70 km/h)	A9 Laden 56 mph
Axle 1	295/80	5860	125 (862)	125 (862)	125 (862)	125 (862)	125 (862)
Axle 2	295/80	9100	60 (414)	40 (276)	90 (621)	90 (621)	96 (662)
Axle 3	385/65	5100	60 (414)	40 (276)	90 (621)	90 (621)	96 (662)
Trailer	11 R 22.5	7600	72 (496)	42 (290)	65 (448)	96 (662)	96 (662)

Appendix F

TIREBOSS TPC SPREADSHEET

This spreadsheet was jointly developed by Tire Pressure Control International Ltd and the Forest Engineering Research Institute of Canada to assist in estimating potential benefits that could accrue from implementing the “TIREBOSS” tyre pressure control system in a typical trucking operation. The spreadsheet is well constructed and takes the reader logically through a range of financial and operational in a series of understandable steps.

Considerations that are costed in the spreadsheet include:

• Baseline general costs	Operating costs & revenue, vehicle costs, labour costs, labour times, internal & external charges, material costs, fuel consumption, fuel cost
• TIREBOSS capital cost	TIREBOSS hardware, vehicle compressor upgrade (if necessary), local taxes
• Baseline before fitting TIREBOSS	Operating hours, tyre management, tyre problems, punctures, blowouts, repairs, callouts, lost time, bogged vehicles, recoveries, assists, fuel, servicing,
• Estimated benefits as a result of fitting TIREBOSS	Operating hours, tyre management, tyre problems, punctures, blowouts, repairs, callouts, lost time, bogged vehicles, recoveries, assists, fuel, servicing,

Using this data the spreadsheet calculates the anticipated annual savings after fitting TIREBOSS across 3 main parameters: tyre life savings, traction related benefits and fuel consumption depending on the type of off highway usage expected of the vehicle. Three ranges of duty are available: <10% (light duty), 10%-30% (medium duty), 30%-60% (heavy duty) and >60% (severe duty) A screenprint of part of the spreadsheet dealing with tyre and tyre maintenance savings is shown in Figure F1 below. The cells highlighted in yellow are the cells that are input by the user.

Some of the estimated savings suggested are based on research trials and some are based on field experience and impressions. A detailed "References" sheet is supplied with the spreadsheet that lists the sources of the anticipated savings used and how they have been used. The sheet identifies which savings estimates are expected to vary and which are likely to be well defined. The spreadsheet is generally self explanatory to persons with operational experience in the heavy haulage industry but notes are also attached to many of the cells to aid understanding.

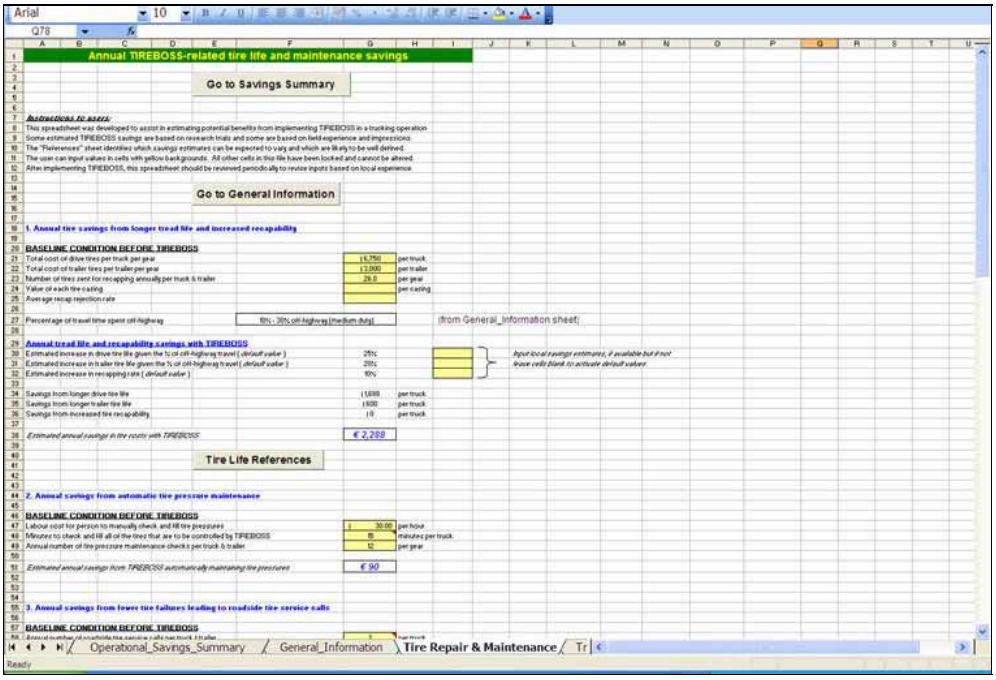

Figure F1 Screenprint of a section of the TIREBOSS spreadsheet dealing with benefits to tyres

A "Simple Payback" sheet and "Internal Rate of Return" (IRR) sheet pull all the results together and includes an illustration of the number of extra operational hours that would be need to be created to reduce the payback period to a required number of years.

The spreadsheet does not cover road owner costs & benefits, intangible benefits such as vehicle ride, reduced driver fatigue, safer vehicle, reduced vehicle maintenance due to reduced vibration, etc but there is an area at the bottom of each of the operational savings sheets where these and other cost/savings items can be entered if desired.

The package has 8 sheets:

- TIREBOSS price data,
- An operational savings summary;
- General operation;
- Tyre repair and maintenance
- Traction benefits;
- Fuel savings;
- A "Simple Payback" estimation and
- Internal Rate of Return;
- References

TPCS references from Tire Pressure Control International

The following references have been abstracted from the TIREBOSS TPC spreadsheet prepared by Tire Pressure Control International. They are given as illustrations of the range of trials that have been carried out on TPCS in North America and the information gained.

Tyre repair and maintenance

Influence of under-inflation on tyre life, tread wear and roadside service call frequency.
A 2002 study of OEM's by Technology & Maintenance Council surveyed over 6000 trucks and found these key findings:

- approximately 19% of tyres in fleets of < 50 trucks were under-inflated by 20 psi or more
- 1 out of 5 trucks had at least one tyre that was under-inflated by 20 psi or more
- 3% of all trucks have 4 or more tyres under-inflated by 20 psi or more
- mismatched duals are a problem: 20% of drive tyre duals varied by 20+ psi; 25% of trailer tyre duals varied by 20+ psi

Incorrect inflation pressure results in increased tyre wear and reduced tyre life, and more frequent roadside tyre service calls

- Constant 20 psi under-inflation from recommended inflation pressure causes a 30% reduction in tyre life
- Constant 20 psi under-inflation from recommended inflation pressure causes a 25% increase in tread wear

Field Experiences of tyre life and tread wear with TPCS

- FERIC CTI-equipped truck in Lumby, BC experienced a 90% increase in drive tyre life during heavy duty use in 1989-1991 testing (FERIC Technical Note TN197. Bradley. June 1993).
- Mallock Trucking at Al-Pac experienced about 35% longer drive tyre life between TPCS/ non-TPCS trucks in heavy duty use in 2002
- FERIC Star Truck in St. Omar, QC experienced 40% increase in drive tyre life during heavy duty use in 2000-2001 testing (Anonymous 2002. Strategic Partnership between Canadian Forest Service and FERIC. ARBOR Business Plan. FERIC Profile for NRCan-CFS. 17pp. April 2002).
- Weyerhaeuser TPCS trucks in Arkansas/ Oklahoma operations experienced 27% longer drive tyre life in medium duty use in 2002 (source: TPC International summary prepared for Weyerhaeuser in 2002).
- Abramson Enterprises of Regina, SK realised an estimated 20-25% longer tyre life in medium duty use over three trucks from 1996 to 1999 (source: testimonial letter to TPC International)
- NATC test found 15% less drive tyre wear and 13% less trailer tyre wear on a closed-loop test circuit in 1987 (light duty) (Ashmore 1987 CTI. Final Report. Nevada Automotive Test Center).
- Weyerhaeuser TPCS trucks in Washington State operations experienced 0-5% longer drive tyre life in light duty use in 1993

Field experiences of fewer roadside service calls with TPCS

- Weyerhaeuser trucking contractors reported going from an average of 1 flat tyre per month to 1 flat per 7.5 months (WeyCo AR/OK CTI Project report January 2003).
- Weyerhaeuser trucking contractors reported going from an average of 2 to 0 broken inner wheels per 9 month hauling period (WeyCo AR/OK CTI Project report January 2003).
- A TPCS-equipped self-loading log truck in Grande Prairie, AB used run-flat setting to keep a badly punctured steer axle tyre inflated for over 40 km to reach the tyre repair facility in town (1998 FERIC field tour).
- CTI-equipped truck in Lumby, BC experienced a 100% decrease in tyre punctures during an 18-month test (FERIC Technical Note TN197. Bradley. June 1993).

Field experiences of fewer in-house service calls with TPCS

- Weyerhaeuser trucking contractors reported going from an average of 1 flat tyre per month to 1 flat per 7.5 months (WeyCo AR/OK CTI Project report January 2003).
- CTI-equipped truck in Lumby, BC experienced a 100% decrease in tyre punctures during an 18-month test (FERIC Technical Note TN197. Bradley. June 1993).
- Weyerhaeuser hauling contractors in Arkansas and Oklahoma reported a 30% longer tyre change interval saving in tyre shop costs and associated downtime.

Traction benefits

Field experiences of vehicle assists with TPCS

- Glen Wyrick reported improved ability to haul under wet road conditions in Arkansas. His TPCS-equipped trucks had to pull the other trucks up one hill when it was wet (WeyCo AR/OK CTI Project report January 2003).
- Bruce Hopson in Oklahoma claimed a 20% -30% gain from his skidders and bulldozer productivity because TPCS virtually eliminated his trucks getting stuck in 2002 (WeyCo AR/OK CTI Project report January 2003).
- D & H Trucking of Hudson Bay, Saskatchewan reported 100% decrease in vehicle assists for B-trains on new, wet block roads in July 2003 (FERIC Advantage Report Vol.3 No. 6 Blair and Bradley 2004).
- Harold Clark Logging of Berry, Alabama had a 100% decrease in vehicle assists, and 3.5 - 4 weeks extra hauling on wet roads in 2005 (customer feedback documented by TPC International, August 2005).
- Michael Franks Logging of Winfield, LA reported a dramatic decrease in vehicle assists and associated skidder productivity (customer feedback documented by TPC International, August 2005).

Field experiences of less tire chain usage and wear

- LoBar Transport of Drayton Valley, Alberta has reduced the use of tire chains from every wintertime trip to an estimated 5 times per winter (reported to FERIC in 1999).
- CTI-equipped truck in Lumby, BC experienced a large, unquantified, decrease in tire chain use in 1989-1991 testing (reference FERIC Technical Note TN181 Bradley 1996)

Fuel savings

Field experiences with fuel savings

- The national tire companies estimate an increase in fuel efficiency of 2% to 10% due to constant inflation maintenance as compared with documented industry maintenance practices.
- Published research trials on the effect of TPCS on fuel consumption vary considerably, however, none except the FERIC Huntsville trial were done under the formal SAE test procedure.
- NATC (1987) reported a 2.5% increase in fuel consumption for TPCS trucks at 21% sidewall deflection (39 loaded - 19 psi unloaded) on hard-surfaced roads vs. 90 psi
- Watkins (1991) reported that two USFS tests found negligible fuel consumption differences for log trucks operating with 65 - 70 psi vs. 90 psi on long round trips Jones and Smith of LIRO (1992) reported a 4% increase in fuel consumption over 4 months for travel at a constant reduced pressure giving 20% sidewall deflection on hard road operation.
- 2005 measurements in Sweden by Skogforsk found that fuel consumption was unchanged for paved road travel, and improved by 0.3 -0.5 L/km for empty and loaded off-highway travel, respectively.
- 2000 measurements in Saskatchewan by Saskatchewan DOT found approximately 9% decrease in fuel consumption daily at 65 psi vs. 100 psi on a 75% gravel route (unpublished).

ROADEX III NORTHERN PERIPHERY

ROADEX III PUBLICATIONS

Developing Drainage Guidelines for Maintenance Contracts

Tyre Pressure Control on Timber Haulage Vehicles

Understanding Low-Volume Pavement Response to Heavy Traffic Loading

Health Issues Raised by Poorly Maintained Road Networks

Road condition management policies for low volume roads – tests and development of proposals

Policies for Forest Roads – Some Proposals

Road Construction in Greenland - The Greenlandic Case

SKOGSSTYRELSEN SWEDISH FOREST AGENCY
VEGAGERDIN
The Highland Council
Forestry Commission Scotland
FINNISH ROAD ADMINISTRATION
ROADSCANNERS
Statens vegvesen
Vägverket