Why TPCS? Why Now?

Low Impact Vehicles and TPC
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Where we call home

- Vancouver
- Edmonton
- Toronto
- Montreal
Outline

• CTIS to TPCS
• Variable tire pressure principles
• VTP and roads – research highlights
• Government TPCS Initiatives
• Why TPCS? Why now?
CTIS to TPCS
Development of CTI Systems

- 1942 US amphibious landing craft.
- 1950 US prototype truck with internal axle.
Development of CTI Systems

• 1942 US amphibious landing craft.
• 1950 US prototype truck with internal axle seals.
• 1944-1960 Soviets develop internal axle seals and adapt CTI to trucks; widespread use.
• 1960-1970 widespread use by Warsaw Pact; adapted to log truck, oilfield transport; airplanes; developed CTI-ready tire designs.
Development of CTI Systems

- US desert ambitions fueled re-adoption of CTI in 1980s; reverse engineered and redesigned for modern trucks and technologies
- Widespread adoption by US and western European militaries in 1990s;
- By 1990, 30+ types of CTI used around world

- In 1982, USFS began CTI research program; applied to various forestry vehicles
- In 1993, first two TPCS for commercial trucks
Soviet VTP tires

- improved off-road mobility
- increased draw-bar pull in low-bearing-strength soils
- improved performance over snow
- improved ride over rough terrain
- run-flat capability (with a CTIS)
- but…shorter life
VTP tires used by the US military

Michelin XL  
Goodyear AT-2A  
Michelin XS
Like CTIS, TPCS allow operational use of VTP.

TPCS were developed to meet the specific needs of commercial trucks.
Development of TPCS

SAE Recommended Practice for CTI System Performance Requirements (1993 DRAFT)

CTIS (TPCS) should allow for:
  • Adequate air drying capacity
  • Isolate leaking tires and manual re-inflation
  • Operation under extreme service conditions
  • Readily understood display, with audible and visual warnings in case of speeding or low air
  • Air brake priority over CTIS (TPCS)
  • Pressures/ speeds/ loads as per Tire &Rim A.
  • Reach 80%/ 100% of target in 5/ 15 minutes
  • 10% or 3 psi accuracy
Development of TPCS

Additional design elements developed through field testing or required by regulators

TPCS should include:
- 75%/100% of target in 15/ 25 minutes
- Auto inflate in case of speeding
- Pre-programmed inflation mode settings based on tire manufacturers’ recommendations (TRA)
- Allow for normal heat build-up with tire operation (e.g., +10-15% (<15 psi))
- Only flexible, air brake quality, elements extend past width limit
- Ability to be monitored by OBC (optional)
TPCS components
Over 1000 TPCS in use in Canada
Variable tire pressure principles
Inflation changes footprint size and shape
Reducing tire pressure causes fundamental changes to the tire-road interaction

- **Rut shape**: Wider, shallower rut
- **Stiffness and spring rate**: Less impact energy
- **Contact area**: Lighter footprint, more tread
- **Contact stress distribution**
Truck tire load/ speed/ inflation

- **Industry Norm**
- **Design Footprints**

<table>
<thead>
<tr>
<th>Tire Load (kg)</th>
<th>Cold Tire Inflation (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>80</td>
</tr>
<tr>
<td>1400</td>
<td>56</td>
</tr>
<tr>
<td>1900</td>
<td>105</td>
</tr>
<tr>
<td>2400</td>
<td>2100 kg</td>
</tr>
<tr>
<td>2900</td>
<td></td>
</tr>
</tbody>
</table>

- **Cold Tire Inflation (kPa)**
- 200
- 300
- 400
- 500
- 600
- 700

- **Speeds:**
  - 56 kph
  - 80 kph
  - 105 kph
Uncontrolled tires are over-inflated for 75% of the trip.
Changes in tire stress with low pressure

Source for next 4 slides:
Randy Clark, Michelin Tire
SAE Paper 933059

620 kPa $\rightarrow$ 350 kPa. (Load 1930 kg)
because road hazards come in many forms
Mud traction and tread life

- Mud traction
- Tread life

Percent of full ability

Cold Tire Inflation Pressure (kPa)
Motion resistance – incline effect and tire pressure

Two tires with same load, rut depth, tire size

High pressure

Low pressure

Steep incline

Shallow incline

Lower pressure has less motion resistance
reduced inflation might have helped…
...but it won’t let you walk on water
What is possible with reduced inflation?

<table>
<thead>
<tr>
<th>Road surface</th>
<th>Highway inflation (kPa)</th>
<th>TPCS tire pressure (psi)</th>
<th>Measured tractive increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose gravel*</td>
<td>610</td>
<td>210</td>
<td>42%</td>
</tr>
<tr>
<td>Sugar sand</td>
<td>690</td>
<td>450</td>
<td>34%</td>
</tr>
<tr>
<td>Wet clay</td>
<td>690</td>
<td>450</td>
<td>17%</td>
</tr>
</tbody>
</table>

* Less or no tractive hop at reduced tire pressure
Getting unstuck from sand

Reduce tire inflation and rock to & fro
TPCS soft ground mobility demo

- - - - - - - - - - - - HP

- - - - - - - - - - - - LP drives

- - - - - - - - - - - - LP all tires
TPCS soft ground mobility demo

Trailer tires strongly influence truck mobility
TPCS soft ground mobility demo

- O passes
- 3 passes
- 12 passes

HP
LP drives
LP all tires
Climbing steep grades when unloaded
Climbing steep grades when loaded
VTP and roads - research highlights

Forest Transportation Research Project

Testing of
Tire Pressure Control Systems
Under Special Permits

Info. 705-744-5563 or www.feric.ca

Tembec
IRD
FERIC
Ontario
Summary of USFS findings (1982-2002) on variable tire pressures & resource roads

- Enhances traction and mobility under steep or slippery conditions
- Slower rutting rate – especially on very weak roads and for low traffic volumes. Wider, shallow ruts
- Less gravel loss (less dust control & re-gravelling)
- Reduces pot holing and washboard
- Heals existing damage (ruts and washboard)
- Reduces or eliminates maintenance grading
- Less environmental impact (sediment & erosion, dust)
- Reduces structural requirements (thinner base)
Surfacing Thickness Program (USFS)

STP-predicted Rut Depth with TPCS

- Predicts slower rutting with low pressure.
- Greater improvements on weak roads and at low traffic levels.
- Field trials confirm 50+% slower rutting.
- Predicts reduced structural requirements for TPCS-dedicated roads.
- Field trials confirm 25% thinner base possible and this reduces road costs by 25%.

![STP-predicted Rut Depth with TPCS graph](image-url)
Spring thaw problems on county roads are mostly due to fines in the road base rather than base thickness.

In order to reduce overall road deterioration in the spring-thaw period, NRA recommend using:
• lighter axle weights
• dual tire assemblies in place of single tires
• lower tire pressures ***
• reduced travel speeds
• night operations (to take advantage of night frost)

***estimated to have the greatest impact
Vertical stress distribution in a low standard road using layered elastic theory

Largest stress reductions occur in surfacing and base layers
Inflation pressure and pavements literature

- Many studies on inflation pressure in the literature.
- Most studies are for pressures > 518 kPa but radial truck tires increase footprint rapidly below 345 kPa (50 psi).
- Layered elastic modeling predicts smaller strain reductions in thicker and stiffer A/C pavements.
- Thick A/C are less susceptible to fatigue cracking than thin A/C.
Effect of tire pressure on pavement strains

• Thin A/C experiences higher strains at the bottom of the mat than thick A/C.
• Transverse strains are more sensitive to low tire pressure than longitudinal strains but both respond.
• Steering tires create larger transverse strains than longitudinal strains; the reverse is true for dual-tired assemblies.
• Truck steering tires are fewer and have less pavement impact than the dual-tired assemblies, however, their impacts become more comparable at lower tire pressures.
Inflation and strains in thin and thick A/C (Wang, Machemal 2006)
Preliminary results (U. Laval)

Average peak transverse strain reduction (690 -> 380 kPa)
Effect of tire pressure on pavement strains

Impacts of heavily loaded single tires could be reduced with lower pressures
Tire pressure and pavement life (Huhtala 1989)

Reference axle is 10 tonne single axle with 12R22.5 dual tires at 700 kPa.
Effect of tire pressure on dynamic loading

• Truck dynamic axle loadings = 2 to 14x static loadings at rough spots on A/C depending on suspension, speed, bump size, load, etc. (Cebon 1993).

• Damage propagates from these rough spots.

• 200 kPa tires imparted 1/6 vertical energy of 690 kPa tires on smooth pavement and 1/7 on 5 cm-high washboard (NATC 1987).

• Lower tire pressures transmitted 38-43% smaller RMS accelerations and noticeably improved ride of Montreal bus (Rakheja and Wang 2006).
Government TPCS initiatives

Some are skeptical about government initiatives...
• First jurisdiction in North America to promote TPCS use on secondary highways (1998).
• TPCS trucks can haul primary highway weights on secondary highways with no incremental road damage fees (for approved routes and with applicable monitoring).
• TPCS-trucks permitted heavier SLR weights.
British Columbia TPCS SLR initiative

- Truck-based data logger gathers route, speed and tire pressure info that is reported with measured axle weights. Trip info is decrypted, summarized in a compliance report, and posted to a secure website within 3 minutes.
- Program is open to all industries with forestry leading this initiative.
Reduce tire pressure - not payload!

"Road friendly" truck starts when its road consumption rate equals the baseline condition.

Surface Rebound

<table>
<thead>
<tr>
<th>1.5 mm</th>
<th>1.25 mm</th>
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<tbody>
<tr>
<td>frozen</td>
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SLR

3 - 4 weeks

recovery

springtime

Road consumption rate from "road unfriendly", legal truck at end of SLR period is the baseline condition.
Ongoing TPCS SLR initiatives

Ontario government and forest industry start an industry-managed TPCS-SLR Haul Program in spring 2011.

- Industry association audits and manages participants and negotiates with government.
- 3rd party consultant documents road changes.
- Applicant responsible for repair costs of accelerated road damage.
Ongoing TPCS SLR initiatives

- Manitoba government, FPInnovations, and U.Manitoba and U.Laval working with instrumented pavements to evaluate VTP effects.
- Targeting introduction of TPCS-SLR initiative in 2011.
- Modeling to assess reduced incremental road damage fees for TPCS trucks in Manitoba TIPP.
TPCS SLR policy progression in Canada
Why TPCS? Why now?
Driving forces for industry

• Need for more traction with increasing trailer size and payloads.
• Need for enhanced mobility and reduced rutting for summer operations; combined with poor drainage, lack of gravel, heavy payloads.
• Drive to reduce inventories (especially in spring).
• Government initiatives of road-friendly trucks.
• Need for more stable wood flows.
• Need to access timber in sensitive habitat areas.
Additional benefits

• Reduced flats and tire damage, and downtime.
• Longer tire life and improved recapping success.
• Fewer stuck trucks and related recovery costs.
• Less vibration-related damage to driver and truck.
• Increased truck productivity and revenue.
• Better working conditions and driver retention.

<table>
<thead>
<tr>
<th></th>
<th>Laden</th>
<th>Unladen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1&amp;2 gravel road</td>
<td>+2%</td>
<td>+7%</td>
</tr>
<tr>
<td>Class 1&amp;2 gravel road</td>
<td>+2%</td>
<td>+5%</td>
</tr>
<tr>
<td>Soft in-block roads</td>
<td>+30%</td>
<td>+14%</td>
</tr>
</tbody>
</table>

*Measured with formal SAE test procedure*
Implementation strategies are keys to success

• All stakeholders can benefit:
  – vehicle owners/ contractors/ drivers
  – forestry companies
  – traveling public and road regulators

• Strategies and tools have been created to assist with successful implementation.

• Develop champions and address stakeholder resistance, optimise TPCS use, build a business case, change operations and policies to capitalize on new abilities.
Recap

- Contact footprint, contact stresses and sidewall stiffness (i.e., traction, mobility, ride performance) are optimized to the haul.
- TPCS allow operational use of VTP; some allow monitoring for compliance.
- Reduced road impacts – especially on weak, lower standard roads and when traffic is light.
- Regulators in Canada recognize the beneficial impact of reduced tire pressures in current and anticipated initiatives.
- Industry is turning to TPCS to solve wood supply issues and reduce transport costs.
An opportunity exists

• Proven, dependable TPCS systems are now being introduced into the Scottish forest industry.

• An opportunity exists for the industry to coordinate research and/or implementation efforts within their own operations, and with other road user groups (e.g., Roading Authorities).
One vision
Global competitiveness

Thank you

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