Session 5
Paper (c)

CENTRAL TYRE INFLATION (CTI)

An overview of recent USDA Forest Service Field Trials

Colin Ashmore[1]
Ed Gililland[2]

The USDA Forest Service's San Dimas Equipment Development Center has undertaken a study to look at the effects of tyre inflation pressures on log-truck performance and forest roads, and the implications these pressures may have on road construction and road maintenance costs. The literature indicated that truck tyres inflated to highway pressures damage unpaved forest roads and shorten the life of low standard paved roads. The ability to control tyre pressure with an on-board system offers many advantages and introduces a revoluntionary element to existing truck/tyre/road systems.

A Central Tyre Inflation (CTI) system gives an off-road haul truck the ability to match the tyre pressure to the road conditions. The truck can operate at tyre pressures appropriate for the speed, strength, and surface quality of the road being negotiated. For example, an 18-wheel log truck can run 310-345 kPa (45-50 psi) on unpaved forest roads, 515-550 kPa (75-80 psi) on low standard paved roads, and 655-690 kPa (95-100 psi) on high-speed paved highways. Each pressure can be set from inside the cab of the truck while the truck is moving. For the prototype system, used in the Alabama tests (fig. 1), response times for a 10-wheel truck averaged about 13 minutes to inflate the tyres from 310-690 kPa (45-100 psi) and approximately 7 minutes to deflate them from 100 to 45 psi. A 227 litre (60 gallon) reserve air tank allowed tyre pressures to increase quickly from 310-517 kPa (45-75 psi), about 4-5 minutes. After that, the air was supplied by the compressor and inflation time was longer. These times could be improved with a larger compressor and additional reserve air tank capacity. A priority valve ensures that the brake system is always charged.

Structured Tests - USDA FS, Engineering Research Laboratory, Auburn, Alabama

The tests in the South have been conducted by the USDA Forest Service's Engineering Research Laboratory in Auburn, Alabama. The tests were designed to document road maintenance differences. These tests showed that loaded log trucks with tyres at 690 kPa (100 psi) damaged forest roads, whereas low tyre pressures did not. Road failure was defined to be when the road became impassable to the trucks under their own power. Many companies do routine maintenance so our definition of road failure may seem severe.

---

1. Colin Ashmore is Research Engineer with the USDA Forest Service, Southern Forest Experiment Station, Auburn, Alabama, USA.
2. Ed Gililland, CTI Programme Leader, San Dimas Equipment Center, San Dimas, California, USA.

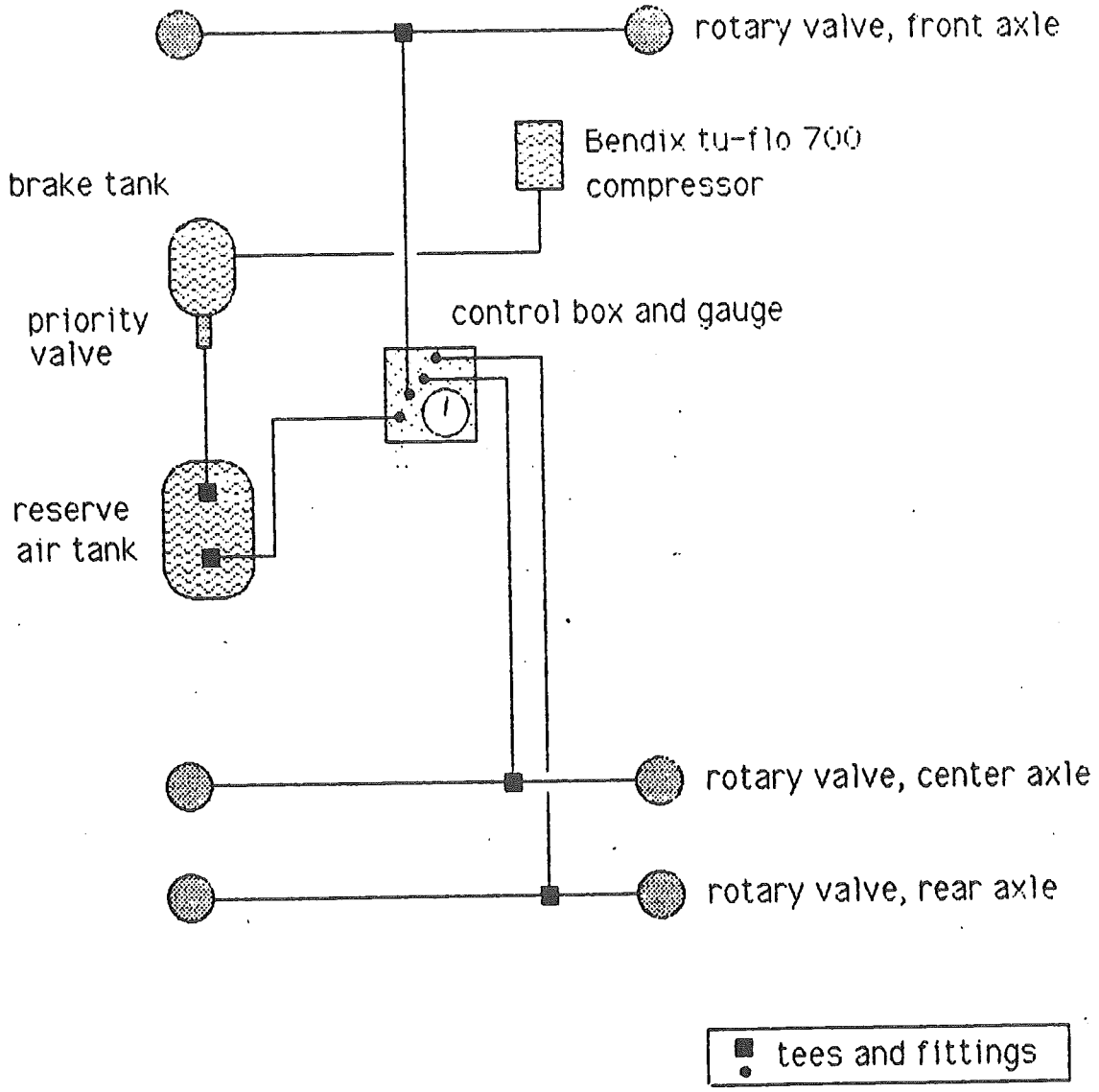

Figure 1. Schematic of CTI system for 10-wheel log truck.

A 4.8 km (3 mile) section of a good quality, unsurfaced, sandy forest road was divided into 3 sections with turnarounds at each end. The turnaround areas were bladed out beside the road and represented an off-road landing or deck area. The first section (1.6 km) of road after the turnaround was restricted to approximately 690 kPa (100 psi) in all tyres (10% deflection), the second section to about 450 kPa (65 psi) in all tyres (20% deflection), and the third section to 207 kPa (30 psi) (30% deflection). Two 10-wheel log trucks, fitted with prototype CTI systems, were loaded to legal limits and driven back and forth on the road.

The tyres were run at constant deflections rather than constant inflation pressures because it was desirable to keep the spring rate of the tyres constant, thus keeping the dynamic loading experienced by the truck and road constant.

Tyre Data : 11Rx24.5 Michelin tubeless radial tyres (XZY tread design)

Truck Data : R686ST Mack trucks with :

224 kW (330 hp) Maxidyne engines
6 speed transmissions
4:17 final drive ratios
log bunks for hauling 5.2 m (17 ft) sawlog material

Truck weights : 21.8 tonne loaded with 6.8 tonne tare weight

Road Data :

- 268 passes loaded, 90 passes unloaded.
- The section of road subjected to 690 kPa (100 psi) failed and became impassable by the end of the tests. The rest of the road that was passable was rutted. The two sections travelled at 450 kPa (65 psi) and 207 kPa (30 psi) showed very little road wear and were in as good condition as when the test started. The only difference between the test sections was tyre pressure.
- Two concrete culverts were completely broken through in the section of road subjected to the tyres at 690 kPa (100 psi). There were two similar culverts in the section of road subjected to 207 kPa (30 psi) that did not break.
- When the trucks got stuck in the high pressure turnaround, the driver lowered the tyre pressure to 310 kPa (45 psi) (from inside the cab) and pulled away without slipping.
- Ride comfort was greatly improved with the low pressure tyres.
- There were no tyre failures during the test.
- There was a 2-gear-difference between the truck with tyres at

690 kPa (100 psi) and the truck with tyres at 207 kPa (30 psi) pulling through a section of road that was very near the failure point (impassable). The truck with low pressure tyres operated in the higher gear.

- Low pressure tyres were used to heal the rutted high pressure section. In the remaining portion of the high pressure section that was still passable, additional passes with 310 kPa (45 psi) tyre pressures were made. The drivers alternately drove to either side of the ruts, producing a pneumatic roller effect that smoothed out the rutted areas and improved the road surface.

- Overall, 450 kPa (65 psi) was the preferred inflated pressure by the drivers.

- A significant difference in mobility between the 690 kPa (100 psi) and either the 450 kPa (65 psi) or 207 kPa (30 psi) inflation pressures were noticed in the turnaround areas. After the first rain, the high pressure turnaround area could no longer be used without the trucks becoming stuck. In the low pressure turnaround, the trucks never became stuck, even after substantial rains during late November and early December.

- The final report should be available June 1987.

Drawbar Pull Tests - USDA FS, Engineering Research Laboratory, Auburn, Alabama

To document the significant differences in mobility, drawbar pull tests were conducted on a sandy and a saturated clay road. A 9.0 tonne (20,000 lb) load cell was put between the loaded, 10-wheel log truck and a Franklin 170 forwarder. In its lowest gear, the truck pulled the forwarder until both reached a steady speed. To increase the pull demand on the truck, the brakes on the forwarder were slowly applied. If this did not produce 100 percent slip on the truck, the pull resistance to the truck was increased by slowly lowering the forwarder blade into the road.

- These tests showed a 34 percent increase in drawbar pull on the sandy road and a 17 percent increase on the clay road between 690 kPa (100 psi) and 450 kPa (65 psi), with the higher pull at 450 kPa (65 psi).

- There was not a significant difference in drawbar pull between 450 kPa (65 psi) and 207 kPa (30 psi).

- The final report should be available in June 1987.

Field Test - USDA FS, Engineering Research Laboratory, Auburn, Alabama

Until an interim tyre standard is approved by the Tyre and Rim Association that supports the use of lower tyre pressures, all tests have to be conducted on private roads. All of the Forest Service tests are designed to provide the necessary data for the

implementation of a standard for low pressure operation. Such data is presently not available and has previously been considered unimportant by tyre manufacturers, because of the trend toward higher tyre pressures (for highway hauling).

Additional field tests are underway in co-operation with Weyerhaeuser Co. in south eastern Oklahoma, where Weyerhaeuser has 14,500 km (9,000 miles) of company roads. The log bunks were taken off and the trucks were changed to an 18-wheel configuration by adding fifth wheels. The CTI system went to the tractor tyres only. The trailer tyres were operated at 690 kPa (100 psi). In this part of Oklahoma loggers have problems with rocks and stumps cutting the sidewalls of the tyres and bruising the tyres, causing separation. To avoid this damage, loggers are inflating their tyres to 760-830 kPa (110-120 psi). We operated at tyre pressures of 330 kPa (48 psi) loaded and 170 kPa (25 psi) unloaded (except for the front tyres, which stayed at 330 kPa (48 psi) loaded and unloaded). These pressures give a 20 percent deflection for an average payload of 31.8 tonnes (70,000 lbs).

- Both trucks travelled about 1,600 km (1,000 miles) off-highway without any tyre problems and with very little tyre wear (as of February 20). More kilometres are being logged.

- The low pressure tyres had better traction on the push-out roads, on frozen areas of roads, and on adverse grades (18 percent maximum).

- Five times rocks got caught between the duals on the trailer tyres during the high pressure operation, causing a 4-7 minute delay to remove them. These rocks would have most likely caused some tyre failure if not removed. Only once did a rock get caught between the duals on the low pressure truck tyres.

- The drivers liked the ride and the handling of the low pressure tyres.

- Road wear is not a problem in this part of Oklahoma, however there was less sinkage on the push-out roads with the low pressure tyres.

- The trucks on loan from Mack Trucks, Inc. had to be returned, but we are continuing the tests in south east Oklahoma through a co-operative study with Weyerhaeuser Co. and Perry Walters (the contractor that operated the loaned Mack trucks). The CTI system was then installed on one of Walters' trucks and is being operated on Weyerhaeuser's private road network at 345 kPa (50 psi). The average payload is 36.4 tonne (80,000 lbs).

- A final report on the tests in Oklahoma documenting tyre life and possible heat build-up problems this summer is due December 1987.

Structured Tests - Nevada Automotive Test Center, Carson City, Nevada

This test consisted of operating two identical 18-wheel log trucks over a test course designed to evaluate truck and tyre performance. A 1.2 kilometre two-lane course had aggregate test sections with 75mm round rocks, potholes, washboarding, curves and standard obstacles found in the Waterways Experiment Station military test course. The course also had a chip seal and a 50 mm hot mix section. The high pressure truck had 620 kPa (90 psi) in all tyres. The low pressure truck had 380 kPa (55 psi) on the steering axle, 300 kPa (43 psi) on the drive axles, and 260 kPa (38 psi) on the trailer axles for the loaded passes; and 380, 125 and 125 kPa (55, 18 and 18 psi) respectively for the unloaded passes. These reduced tyre pressures gave a 21 percent deflection. The test procedure was 2,000 passes with both trucks loaded, 2,000 passes with both trucks unloaded, and then 3,200 km of highway travel with both sets of truck tyres inflated to 620 kPa (90 psi). The preliminary results indicate :

- Tyre wear shows a slight advantage to the low pressure tyres.
- Fuel economy shows a slight advantage to the truck with high pressure tyres (less than 5%).
- No tyre failures have been experienced to date, although the high pressure tyres show some cuts. No cuts were experienced on the low pressure tyres.
- The high pressure tyres run at higher temperatures than the low pressure tyres.
- Truck maintenance costs are higher for the truck with high pressure tyres. Labour costs for truck maintenance are running three times higher and costs for parts are running ten times higher.
- Accelerometer readings show much higher impacts on the truck with high pressure tyres.
- The amplitude of the washboards built into the course were "ironed out" with the low pressure tyres. With the high pressure tyres, the washboard section became worse (higher amplitudes) and the original length of washboard section was extended along the length of the course.
- The chip seal and 50 mm hot mix sections broke up under the high pressure tyres with additional passes.
- Ride comfort is greatly improved with the low pressure tyres.
- The final report is due June 1987.

Field Test - Olympic National Forest, Washington

This operational test used six Forest Service owned, 10-yard, 10-wheel dump trucks hauling rock to resurface a road. One truck was equipped with a CTI system. The other five trucks were required to use airing stations and deflater valves to adjust tyre pressures. The tyre pressures were set to give the same deflections used in the Nevada tests.

- Tyre problems were reduced. In the past, the crew had 5-7 flats a week with normally inflated bias ply tyres. For the 7 weeks, low pressure radial tyres were used with no flats experienced. Part of this was attributed to low pressure tyres; part to the use of radial tyres.

- In the past, these roads required maintenance every 2-3 days. No maintenance was required during a three week haul with low pressure tyres.

- After three weeks of low pressure hauling, the tyres were returned to their normal inflation pressures. After three days, the Olympic National Forest requested that the tyres be returned to the lower pressures because of road damage and required maintenance. No further maintenance has been required since returning to low pressure tyres.

- No washboarding has been experienced with the low pressure tyres, whereas this haul road normally washboards on curves and grades.

- The drivers felt that the trucks are more stable at the lower inflation pressures, especially while dumping. They experienced a more comfortable ride and easier handling with the low pressure tyres.

- The Olympic National Forest is convinced that all their dump trucks should be equipped with CTI systems.

- The final report will be available in May or June, 1987.

Field Test - Boise National Forest, Idaho

This test was run on an active timber sale. Four 18-wheel log trucks were used to haul 10,000 cubic metres[3] of timber over 17.7 kilometres of native surfaced local road and gravelled country road. Tyre pressures were set at the same tyre deflections as the Nevada tests. Airing stations and deflater valves were used to adjust the tyre pressures.

- Road maintenance was drastically reduced using low pressure tyres. The previous year, road maintenance was continual and the local road had experienced ruts up to 400 mm deep. This year, some minor rutting was experienced with low pressure

---

3. Assumes 1 cubic metre = 170 Board Feet)

tyres in wet spots, but the ruts never got deeper than 75-100 mm deep. A healing effect was noted as the road dried out. No maintenance was required for the 10,000 cubic metre haul.

- No tyre failure was experienced when using low pressure tyres. One tyre was ruined when a rock caught between the duals while the tyres were at high pressure.

- Several days of hauling were allowed that would not have been possible with high pressure tyres.

- The drivers expressed a tremendous liking for the ride of the trucks with lower pressures.

For more information, contact :

Alabama and Oklahoma Tests

Colin Ashmore
U.S. Forest Service
Devall Dr.
Auburn University, AL 36849
(205) 826-8700

Idaho and Washington Tests

Ed Gililland
San Dimas Equipment Development Center
444 E. Bonita Ave
San Dimas, CA 91773
(818) 332-6231

Nevada Tests

Henry Hodges, Sr.
Nevada Automotive Test Center
P.O. Box 234
Carson City, NV 89702
(702) 882-3261