ROADS & TRANSPORTATION

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INSULATION: ONE WAY TO OPTIMIZE THE VISCOSITY OF GEAR OILS AND ENERGY CONSUMPTION IN TRUCKS

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Introduction

Those who must use machinery outdoors, especially mobile machinery, in cool and cold weather conditions usually experience certain operating and maintenance cost penalties particularly during very cold weather. It is also a common belief that these penalties are understated for these periods as parts weakened from stresses during cold weather operation may continue to function for a time but fail later in the year or before their normal expected life has been reached.

The National Advisory Committee on Forest Engineering Research at FERIC has recognized the problem and frequently included it in the discussions which guided FERIC in the setting up of the annual research programs. In response to this interest, FERIC organized the data collection for the road transportation projects in such a way that a better understanding of the effects of cold ambient temperatures on machinery operating conditions would be obtained.

Technical Note "Power Train Component Temperatures in Road Transport Units", summarizes the temperature data which had been collected on the lubricating oils of the driveline components of a logging truck during both controlled testing and normal operation.

For example, Figure 1 shows the temperatures of the power train oils of a loaded truck (64 500 kg G.C.W.) from start-up until their stabilization. The truck had been driven around the Blainville test track at a steady speed of **83 km/h** when the ambient temperature was 7.8°C. Similar data collected on trucks working in their normal operating duty cycle where they are subjected to delays and variations in travel speed, showed that the oil stabilization temperatures may be reached for less than 25% of the duty cycle.

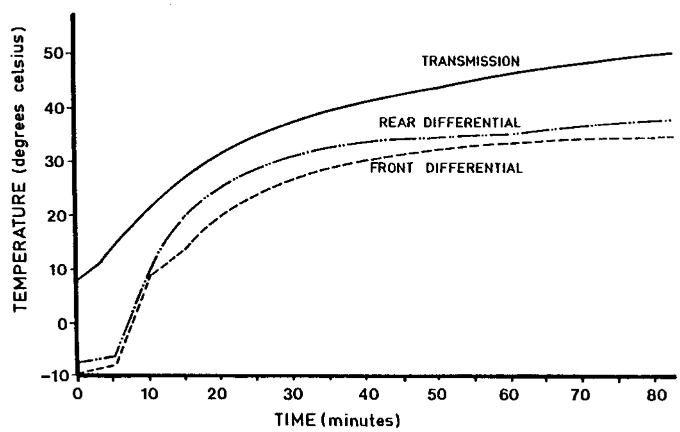

Figure 1. Driveline oil temperatures for a loaded (64 500 kg G.C.W.) forestry truck driven at a constant speed of 83 km/h.

According to Ljubic [1], stabilized drive axle oil temperatures as experienced in Figure 1 might be expected to increase the power demand from the engine by about 430 N (7.2 kW @ 60 km/h) over that required for oil temperatures of 80°C.

This extra power demand is not required to move the truck, but only to rotate the gears in the more viscous lubricating oils. This power is dissipated as heat but only after exacting two costs on the operation. More fuel had to be used to generate this additional power (about 1.5 kg/h according to Ljubic [1]) and the additional power which is completely dissipated in the differentials imposed equivalent higher stresses on the drive unit components to the detriment of expected component life.

KEY WORDS:
Road transportation; Logging trucks; Tractor-trailer combinations; Fuel consumption; Lubricating oils; Viscosity; Axles; Insulation.

Cette Fiche Technique est disponible en français.

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Ljubic [1] reported that measurements taken during the summer (Canada) seldom showed the differential oil temperatures in forestry trucks above the 60°C level. Therefore, any reduction of the viscosity (while maintaining its lubricating qualities) will result in reduced fuel consumption and increased driveline component life (reduced maintenance cost) for all seasons of the year for most Canadian conditions.

There are three ways in which the power losses from churning the oils in forestry truck differentials can be reduced. Preliminary tests have indicated that the differential (and transmission) design is a factor. However, this requires a complex research study as the units must be compared based on power losses and component life (maintenance cost) and would be, at best, a long term solution.

The second method is to use lubricating oils with a flatter viscosity curve through the temperature range encountered in the differentials of forestry trucks. Such oils, synthetic and semi-synthetic, are available and in use. Ljubic [1] and [2] has published studies which compared the effect of regular mineral and selected synthetic oils on power requirements and fuel consumption. However, even these oils are thicker as their temperature is decreased so the power losses in the differentials at the temperatures measured in Figure 1 would still be higher than they would be if some way was found to raise the operating temperature of the driveline components to, say, the 80°C range.

As part of another research study, FERIC staff had to be able to control the transmission and differential oil temperatures. They found the addition of heat to be unnecessary. After all, the power lost in each of the driveline components is converted to heat which is then removed by the air which sweeps under the moving truck. With the selection of the right thickness of an insulation layer and its installation around the differentials, it was possible to raise the stabilization temperatures of the oils to the level required, to reduce the time for stabilized temperatures to be reached, and to reduce the rate of temperature drop during operational waiting and shutdown times. Moreover, not very much insulation was required and no great care had to be taken to ensure that all the awkward shaped and located parts were covered.

This work interested Len Arvelin and his maintenance crew at Great Lakes Forest Products in north-west Ontario and, on their own initiative, they carried out some trials during the winter of 1984-1985. FERIC is very grateful to the management of Great Lakes Forest Products for their permission to publish their results in this technical note.

The GLFP Differential Insulation Project Test Procedure and Results

There were two testing phases. Results from Phase 1 showed that too much insulation had been used resulting in unacceptably high oil temperatures. The insulation was reduced for Phase II and the oil temperature profile has been plotted in Figure 6 for two round trips at markedly different ambient temperatures.

Test Unit Particulars:

- Tractor : Western Star
- Trailers: Superior B-Trains
- Differentials: DT480P (Dual Range 4.33/5.90)
- Gearlube: Gulf 75W90

PHASE I

Insulation Details:

- fully insulated axle housings (Figure 2);
- R12 fiberglass batt-type insulation wrapped around all areas with a double layer (R24) on "nose" section of each carrier;
- all insulation sealed in vapour barrier (Figure 3).

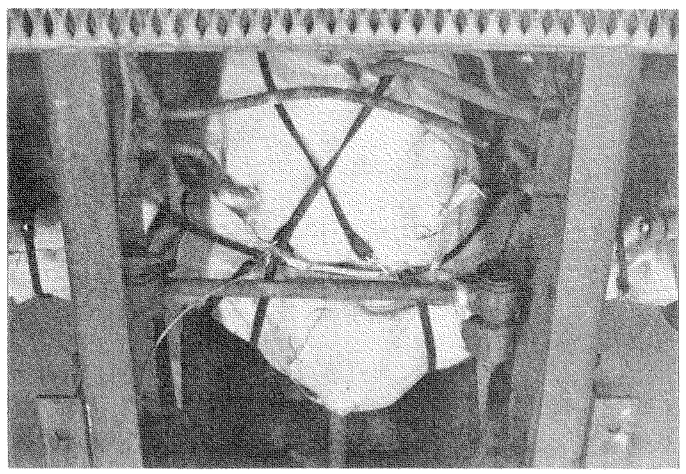

Figure 2. Phase I : fully insulated axle housings (both front and rear) from wheel to wheel.

Both runs of Phase I developed unacceptably high temperatures in the differentials (i.e., above 120°C). Rockwell recommends stopping the unit when the temperatures reach 120°C and the oil supplier states that at temperatures of 70°C and hotter, their 75W90 gearlube decreases in viscosity and no longer supplies an adequate protective film to prevent tooth-to-tooth contact. With these two points in mind, the insulation had to be reduced. Tests on the lube oil did show iron and silicon above normal and numerous large iron particles in the oil sample.

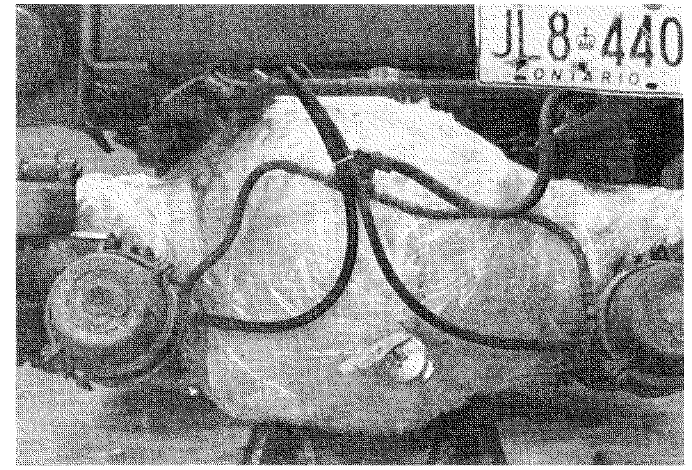

Figure 3. Phase I : full axle coverage with vapour barrier in place.

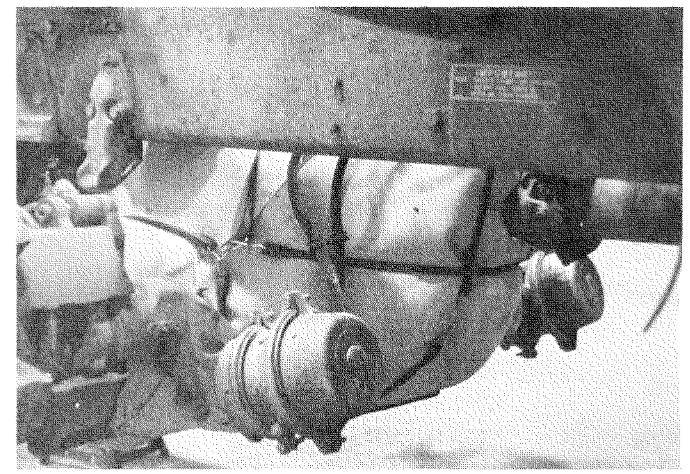

Figure 4. Phase II : centre or "bubble" section only encased by mill felt aver R12 insulation on front or nose section of both drive axles.

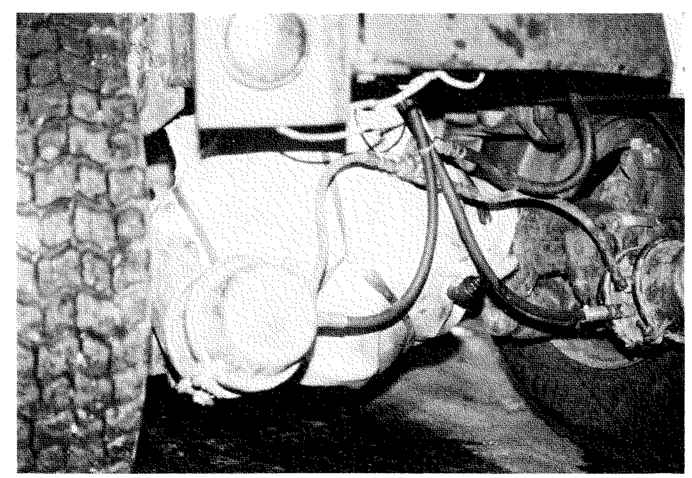

Figure 5. Phase II : axle "tubes" of housings left exposed.

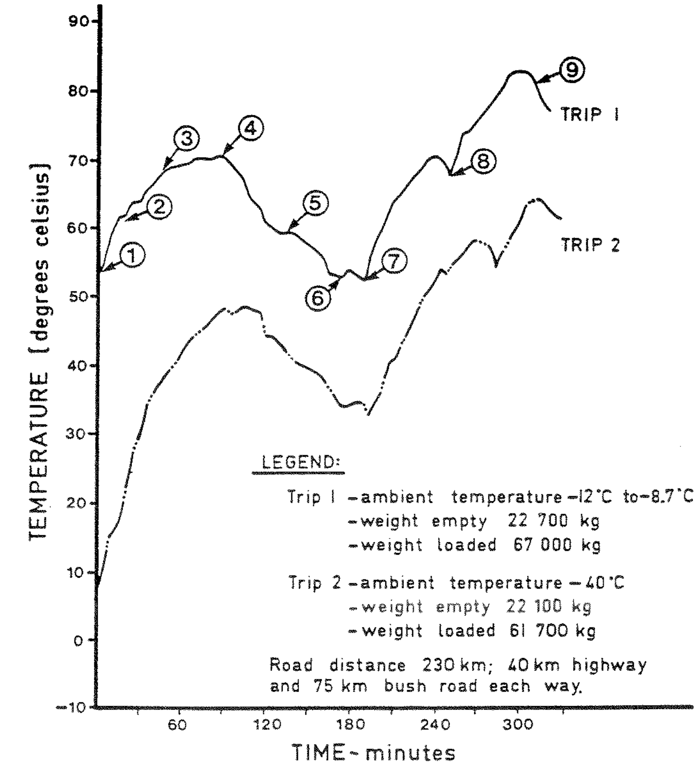

Figure 6. Front differential oil temperatures profile at Great Lakes.
Trip logs:
1. Start from mill yard empty
2. Enter highway
3. Enter bush road
4. On road to landing and park
5. Move to loader and load
6. Leave loader, proceed to bush road
7. Stop to tie down load
8. Stop at load aligner, enter highway
9. To scales

PHASE II

Insulation Details:

- centre or bubble section only encased by mill felt with R12 insulation (Figure 4);
- axle "tubes" of housings left exposed (Figure 5).

The oil in the differentials was changed. The oil temperature profile for the front differential for two round trips on different days has been indicated on Figure 6. (Recordings on the rear axle could not be taken because of thermo-couple failure during trip 2.)

With the higher oil temperatures obtained throughout the round trips with both Phase I and Phase II insulation, the drivers commented that "they could feel the easiness with which the truck rolled" in the cold winter conditions.

Discussion

A series of three different test sequences on different truck-trailer units and at different locations have confirmed the low operating temperatures of the oil in the differentials of logging trucks in Canada. Moreover, while the measured stabilized oil temperatures were approximately 40°C above the ambient temperature, these were only reached for 25% or less of the actual operating time. It took around an hour and a half, after start up, of continuous driving to reach stable oil temperatures and the temperature dropped again during the waiting periods to load and unload.

As more power is required to rotate the differential gears in the lower temperature oils (thicker) to maintain the same truck speed on a given road surface, this extra power must be dissipated in the differential as additional stress on the differential components and, eventually, as heat. Extra fuel must be burned to generate this "lost" power and the fatigue rate of the mechanical components has been increased. These low oil temperatures, therefore, increase fuel consumption and must be expected to shorten the life of differential internals and, with this, increase maintenance costs.

The field tests made by the staff at Great Lakes Forest Products have demonstrated that the oil temperatures in the differentials can be raised to more efficient but safe levels by the judicial placement of insulation.

Conclusion

The makeshift installation as used in Phase II was effective and could be installed on other tractor units but a more "professional" design in which the insulation thickness can be easily changed to suit the season is really needed.

Should insulation be used, it is mandatory that precautionary measures be taken to prevent inadvertent overheating of gear oils. This means specifying the truck with a warning "buzzer" and possibly even a delayed automatic shut down. It also infers that the insulation must be easily removable on the spot.

While these studies were made on forestry trucks, oil temperature profiles should be made on other mobile forestry, mining and construction machinery. Wherever low oil temperatures are found, the opportunity exists for reduced operating and maintenance costs through the judicious conservation or redirection of the heat generated by the engine exhaust or from the power losses in the individual components of the driveline.

References

[1] LJUBIC, D.A. 1984. Analysis of productivity and cost of forestry transportation. PART TWO: Theoretical analysis of the impact of vehicle operating conditions on power losses and experimental determination of the resistance forces attributable to oil churning. Forest Engineering Research Institute of Canada (FERIC). Tech. Rep. N° TR-55. 80 p.

[2] LJUBIC, D.A. 1986. Energy economy through the use of synthetic oils in the engine, transmission and two rear axles of a road transport vehicle. (Prepared for the Transportation Development Centre Transport Canada). TP 8140E. 74 p.