ROADS & TRANSPORTATION

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POWER TRAIN COMPONENT TEMPERATURES IN ROAD TRANSPORT UNITS

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Introduction

Since 1982, FERIC has published four detailed research reports [1, 2, 3 & 4] dealing with the energy consumption profile of the power train components of truck/trailer haul units being used in forestry operations. They are the results of an ongoing research program aimed at measuring the magnitude of, and the interrelationships between, the many variables which affect the power requirements and fuel consumption of logging trucks in the varied Canadian logging environment. Such information is necessary to fulfil the long term objective which is to optimize the productivity and cost of forestry related road transportation.

By using the most recent technological advances, especially in data recording, it has been possible to measure the magnitude of important variables and the interrelationships among them on trucks in their actual working environment. Some of the results differed considerably from the "best guess" numbers which had been accepted as the "likely magnitude" for design and selection purposes within the automotive industry. It was, therefore, necessary to publish the details of the theory of the energy consumption profile used, the methodology of the testing program and the details of the testing equipment and procedure for the scrutiny and criticism of the automotive engineering specialists.

Unfortunately, those sections of the research reports make difficult reading for some of the more practical transportation people in the forestry industry. In line with their suggestions, FERIC will publish a number of secondary transportation technical notes which will present and discuss the research results as they relate to day to day operation. Readers wanting more background theory or information about the testing methodology and equipment are referred to the research reports listed in the bibliography.

KEYWORDS:
Logging trucks; Truck trailer-combinations; Power train; Lubricating oils; Coolants; Temperature; Fuel consumption.

Cette Fiche Technique est disponible en français.

The Engine Coolant Temperature

Anyone who drives a car or truck knows that the engine temperature must not get too hot. Dashboard instruments flash a warning light to alert the driver to take corrective action should this ever occur. We are much less aware of the operating cost penalty if the engine temperature is too low and, as the coolant temperature is controlled by a thermostat, we generally assume that the manufacturer has installed the right one and that it is working correctly.

Figure 1, reproduced from U.S.S.R. reference [5], demonstrates that the temperature of the water in the

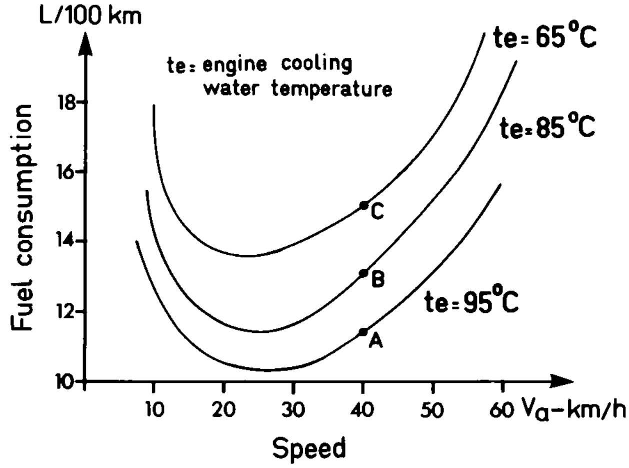

Figure 1. Relationship between vehicle speed and fuel consumption for different engine cooling water temperatures.

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engine is a key factor in fuel consumption. Furthermore, the power drops with the water temperature by some 7 percent from each 10 degrees below 95°C. In the case selected on Figure 1, a temperature drop from 95 to 75°C raises fuel consumption at 40 km/h from 6-7 percent, whereas a drop from 95°C to 65°C results in a 25 percent increase in fuel consumption.

FERIC measured the relationship between engine water temperature and fuel consumption for a North American made engine disconnected from the drivetrain, at a constant engine speed of 1800 rpm. The results are shown on Figure 2. Below 75°C fuel consumption was increased by about 6.5 percent for each 10°C drop in water temperature. The difference seems to be much less pronounced for water temperatures above 80°C.

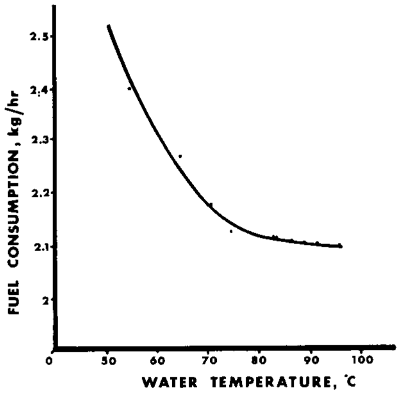

Figure 2. Fuel consumption in terms of engine coolant temperature (engine disconnected from drivetrain).

With the correct thermostat in good working order, the above would have only academic interest. However, in the four fleets FERIC has worked closely with to date, it was noted that a number of trucks had been received from the manufacturer with "hot weather" thermostats. In other cases, the thermostats had become defective so that they opened to cool the engine but remained open for the whole trip. In all cases, a routine checking and replacement of defective or incorrect thermostats would have justified the cost involved.

Lubricating Oil Temperatures in a Working Power Train

The major components of the power train have one thing in common. The engine, transmission and drive axles all have parts which turn or move in a bath of lubricating oil. Energy must be expended to do this and the amount of energy required will have a direct relationship with the viscosity of the oil and the speed of rotation of the moving components. The energy used "to churn the oil" is only one of the major energy consumers in the power train but it is a very important one in temperate climates where much of the wood transport takes place in the cold winter season. From a practical viewpoint, this "energy consumer" is particularly important because it is not affected by the load size or the torque which must be applied to move the truck along the road under the speed/gear relationship selected by the driver. Thus, energy losses caused by oil churning apply to the whole trip--loaded and non-loaded. In fact, they may actually increase on the non-loaded portion if the driver chooses a higher average speed.

As energy losses through oil churning are very dependent on the viscosity of the lubricating oil, and the oil viscosity is dependent on the oil temperature, an obvious starting point for a research study was to determine the lubricating oil temperatures and temperature variability in the driveline components of a forestry transport unit throughout its usual working day. Such data were collected from trucks working on four different logging operations in Québec and Ontario under both winter and summer conditions. As a general statement, the oil temperatures were much lower than had been expected and appeared to reach a stabilized upper limit for probably less than 25% of the normal haulage duty cycle.

To confirm the field results, a controlled experiment was also carried out on the Department of Transport test track at Blainville, Québec where system temperatures were recorded on a truck/trailer unit being driven at selected constant speeds from start-up until the driveline oil temperatures had stabilized. Figure 3 shows a typical temperature/time relationship for a non-loaded and Figure 4 for a loaded truck/trailer combination under average south western Québec winter conditions.

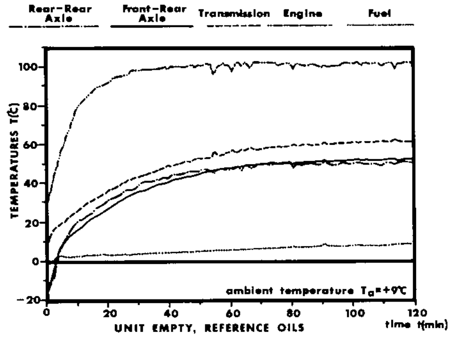

Figure 3. Stabilization test for engine, transmission and rear axle oil temperatures and fuel temperature.

The rise in the lubricating oil temperatures comes from the conversion into heat of that part of the input energy from the engine which is used up overcoming oil churning resistance and from the friction between the moving parts of the driveline components. This heat, in turn, is removed from the system by the air surrounding and sweeping past the underside of the truck. As the heat generated comes from these two major sources, the reason for the shorter temperature stabilization time for the loaded truck (Figure 4) comes from the increased friction loss factor which is the result of the higher applied torque and does not contradict the earlier statement that the oil churning energy loss component is the same for a given speed and oil viscosity for both a loaded and non-loaded truck unit.

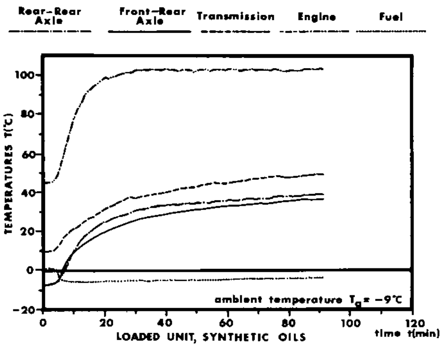

Figure 4. Stabilization test for engine, transmission and rear axle oil temperatures and fuel temperature.

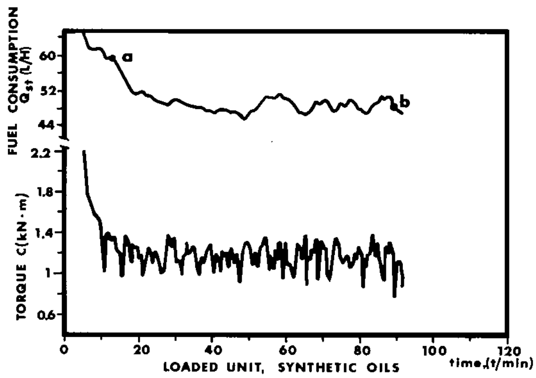

Figure 5. Fuel consumption and torque behind transmission measured during stabilization testing on the test track.

A valid concern of the reader may be that while the above figures show the way the lubricating oil temperature changes with operating time for +5°C and -9°C ambient temperatures, what will they be at the many higher and lower ambient temperatures throughout the working year? An equation (N° 91) in reference [4] was developed which shows that if we know the stabilized oil temperature for one ambient temperature, we simply add or subtract the ambient temperature difference to obtain the approximate stabilized oil temperature at other ambient temperatures. Therefore, if the stabilized temperature for the transmission oil was shown to be 60°C at 5°C ambient temperature, it would be about 70°C at an outside temperature of 15°C.

The Effect of Driveline Oil Temperatures on Energy Requirements

Keep in mind that the purposes of the lubricating oil are to reduce the friction between the moving parts of the driveline components and to remove the heat generated by the friction from the meshing surfaces. The energy loss owning to oil churning is an unfortunate side effect. Therefore, while the oil churning losses can be reduced by reducing the oil viscosity, care must be taken to preserve the lubricating properties of the oil. A deterioration of the lubricating properties of an oil for a given truck/trailer being driven at a constant speed over a flat and uniform road surface would show up as an increase in the drive force which must be applied and an accelerated increase in the lubricating oil temperature. As long as these conditions do not occur, a decrease in oil viscosity through an increase in its temperature would indicate no adverse effect on the lubricating efficiency. Figure 5 shows that the torque required at the drive wheels to maintain the loaded truck/trailer combination at a speed of 83 km/h on the Blainville test track decreased as the temperature of the lubricating oils increased (their viscosity decreased). Thus, less fuel is required to move a transport unit at any given speed if the oil viscosities can be reduced through the controlled increase of the driveline oil temperatures or by the compounding of suitable alternative lubricating oils which have lower viscosity curves.

Lubricating Oil Temperatures for a Working Logging Truck

The oil temperature profiles in Figures 3 and 4 were obtained from a truck driven at a constant speed around the Blainville test track. It doesn't work that way in real life. The speed varies in response to traffic and road conditions and to the action of the driver. There may even be stops, with or without the engine running, along the way.

Figure 6 (Trip 1) records the oil temperature history for the forward drive axle during one such round trip journey of a working logging truck under winter conditions.

Note that, under the low ambient temperature existing at the time, the front differential oil temperature (the only one being recorded) dropped each time the truck stopped. Most of these stops are requirements of the duty cycle (loading, tie down load, check load, etc.). However, an analysis of the Figure 6 (Trip 1) and a second similar truck making the same round trip (Trip 2) is shown for the 115 km non-loaded portion (Table 1).

Table 1. Trip log for the unloaded portion of the trip

	Total time for non-loaded portion	Average speed	Waiting to load	Oil temp. after wait	Oil temp. drop
Trip 1	105 min	66 km/h	25 min	40.6°C	6.1°C
Trip 2	85 min	81 km/h	55 min	34.2°C*	13.5°C

* Corrected to similar ambient temperatures

The higher travel speed of Trip 2 was obtained at the cost of a higher fuel consumption to maintain this speed level and there was an added penalty on the loaded portion of the journey while the oil temperature recovered from its 7.4°C lower starting temperature (and consequently higher viscosity). This shows that an operating cost penalty is incurred when the truck scheduling practice permits higher than necessary travel speeds which only increase the waiting time to load and unload.

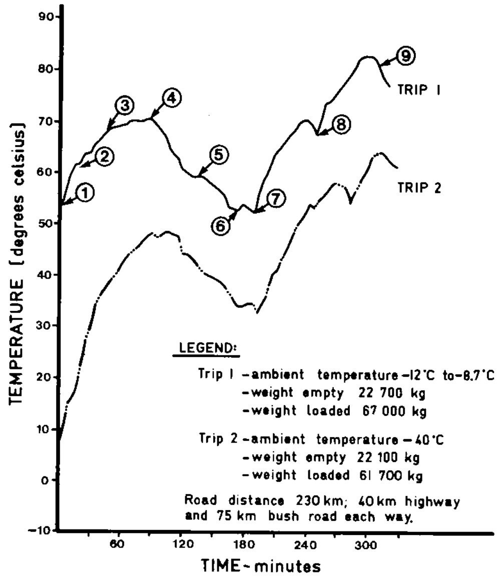

Figure 6. Front differential oil temperature profile from a Great Lakes Forest Products Ltd. truck with two different thicknesses of insulation on the drive axles. The temperature levels are therefore higher than would be obtained with non-insulated axles but the temperature profiles are expected to be relatively similar.

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

The second point to note from Figure 6 is that during the 5 1/4 hour round trip, it is doubtful if the oil ever reached its stabilized temperature. This is similar to the test results reported in references [1] and [2] and has important implications to operators of trucks in cool and cold climates:

a) If engine size and driveline components are specified on the basis of expected 80°C oil operating temperatures, any drop in actual oil temperatures from that level increases the power losses between the engine and the drive wheels. Thus, the "effective power" available from the engine is reduced.

b) As the difference in power to and power from a driveline component increases (because of the higher oil churning losses of more viscous oils), the stress on the components is increased and component life can be expected to decrease.

c) Some of the additives used in the compounding of lubricating oils work under relatively short temperature ranges. It is important for the makers of lubricating oils to know the actual conditions under which their oils will be used.

Conclusion

The FERIC research work (2 & 4) has identified the temperatures which exist at the main power train component of a forestry haulage truck and the effect of these temperatures on the performance efficiency and fuel consumption. Under most Canadian conditions, operating temperatures of the drivetrain lubricating oils were lower than expected. It has been demonstrated that fuel consumption savings are possible if the oil viscosities can be reduced either by raising their working temperatures or by the compounding of synthetic lubricating oils. In either case, this must be done without reducing the oil's lubricating properties. Subsequent technical notes will be published outlining the experimental results which tested the effectiveness of insulation and synthetic oils to attain lower oil viscosities under severe winter conditions.

In this note, a case has also been made for having an effective and correct engine coolant thermostat.

References

[1] Ljubic, D.A. 1982. Analysis of productivity and cost of forestry transportation. Part One: Pilot study to determine the factors for analysis of commercial vehicle power consumption and road performance. For. Eng. Res. Inst. of Can. (FERIC). Tech. Rep. N° TR-53.

[2] 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. For. Eng. Res. Inst. of Can. (FERIC). Tech. Rep. N° TR-55.

[3] Ljubic, D.A. 1985. Analysis of productivity and cost of forestry transportation. Part Three: Theoretical analysis of the impact of vehicle operating conditions on power losses, experimental determination of rolling and air resistance forces. For. Eng. Res. Inst. of Can. (FERIC). Tech. Rep. N° TR-61.

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

[5] Artamonov, M.D.; V.A. Ilarionov; and M.M. Morin. Teoria Abtomobilia I Abtomobilnovo Dvi gatelia, Mashinostroenie, Moscow 1968. 283 p.