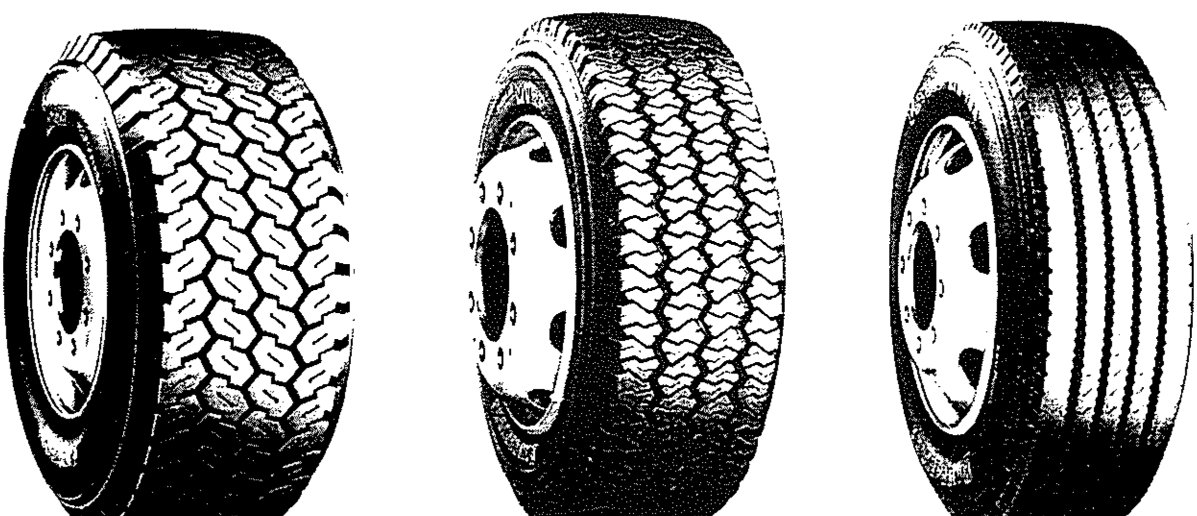
LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

The Relative Fuel Efficiency of Super-Single, Low Profile and Standard Tyres on Logging Trailers

PAUL TAYLOR



SUPER SINGLE LOW PROFILE STANDARD

Project Report

P.R. 48

New Zealand Logging Industry
Research Association (Inc.)
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ROTORUA.

The Relative Fuel Efficiency of Super-Single, Low Profile and Standard Tyres on Logging Trailers

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This report details the procedure and presents the findings of a series of comparative fuel consumption tests done on a 4 km stretch of straight sealed highway near Murupara. The objective of the testing was to determine the relative fuel efficiency of trailers fitted with super-single, low profile and standard radial tyres. The fuel consumed by the truck was metered through a fuel flow metre and the data was logged through an interface onto a portable data logger, which was preset to scan the fuel flow every second.

The recorded fuel consumptions were adjusted for the different gross vehicle weights of the three trailers.

The results found super-single tyres to be approximately 4% more fuel efficient than 11R22.5 radial tyres.

There was no significant difference between low profile and standard radial tyres tested.

Note: This report refers to 11R22.5 radial tyres, super-single tyres and low profile tyres. Technically, super-single tyres come under the heading of low profile tyres, however, for ease of presentation and reader understandability the two have been classified separately.

ACKNOWLEDGEMENTS

LIRA wishes to acknowledge the assistance of Dave Medlicott, Brian Brightwell and Alan Dicker, for the use of their equipment. Also the Kopuriki Stacker Company for supplying and operating their Le Tourneau log stacker.

INTRODUCTION

The need for fuel consumption testing stems from the current worldwide concern over dwindling fossil fuel reserves. Research directed toward the improvement of all forms of energy consumption is in progress. Heavy transport is receiving considerable attention with refinements not only to the internal combustion engine but also to vehicle aerodynamic properties and tyre design.

Over the past few years the transport industry has progressively introduced larger, more powerful trucks that are capable of moving greater payloads faster, safer and more economically. This trend is particularly evident in the logging industry. These larger units and the roads they travel on place heavy demands on tyres and the three basic components of a modern tyre: beads, casing and tread.

Of immediate interest to transport operators is the opportunity to reduce fuel costs. With the cost of fuel accounting for as much as 18% of total costs, any reduction in this area needs further consideration.

TYRE ROLLING RESISTANCE

In 1982 Daniel Ljubic, a researcher with Forest Engineering Research Institute of Canada, conducted a pilot study to determine the factors affecting log truck fuel consumption (Figure 1). The study revealed rolling resistance and the interaction between road and tyre as a major influencing factor in overall fuel consumption. Tyre construction is the most important factor in determining rolling resistance. This resistance is the result of energy absorbed by the tyres as they roll along the road. Most of this energy goes into changing the shape of the tyre when it flattens out on the road surface. This causes flexing of the tyres and "tread squirm" as the tread contacts the road. The more tyre material involved, the more energy absorbed. There are five factors that contribute to a tyre's rolling resistance:

- tread depth
- tread design
- rubber compound
- belt design
- casing design

TRAILER DESIGN

One of the most cost efficient configurations for transporting short logs in New Zealand is an 8 x 4[1] truck and four-axle trailer (Taylor, 1989). That report highlighted the importance of the relationship between repairs and maintenance costs, road user charges and tare weight. Four-axle trailers for short log cartage trailers are obviously the preferred option when buying road tax and generally return cheaper repairs and maintenance costs. The major disadvantage of four-axle logging trailers however is their in-bush utilisation and the tare weight they present to bush loaders.

In an attempt to address these problems, Rotorua log cartage contractor Dave Medlicott designed and built a four-axle short log trailer on super-single tyres with a tare weight of 4520 kg. Medlicott's trailer on super-single tyres has four axles to avoid a possible roll-over in the event of a puncture or blow-out. Four-axles are also desirable when running super-singles, as under the new weights and dimensions legislation the allowable on-highway gross operating weight per axle has been reduced from 8.2 tonnes to 7.2 tonnes.

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[1]*An 8 x 4 truck has eight sets of wheels (on four axles) with four sets driving (on two axles). Also known as twin steer, tandem drive.*

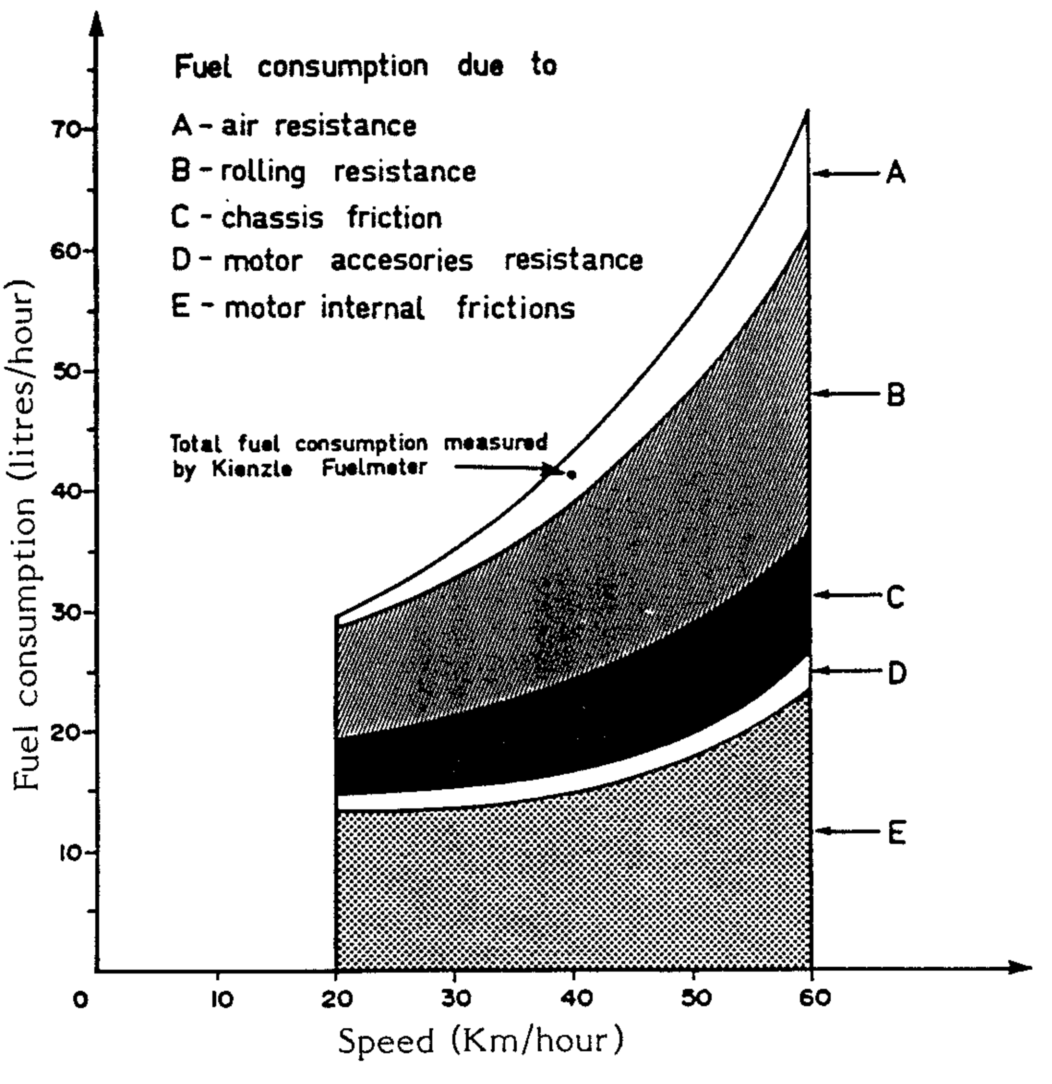


Figure 1 : Factors affecting log truck fuel consumption (Ljubic, 1982)

In this study, the fuel efficiency of Medlicott's trailer was compared with two other four-axle short log trailers, fitted with low profile and standard radial tyres respectively. The trailers were loaded with exactly the same payload and towed over a pre-analysed stretch of sealed highway.

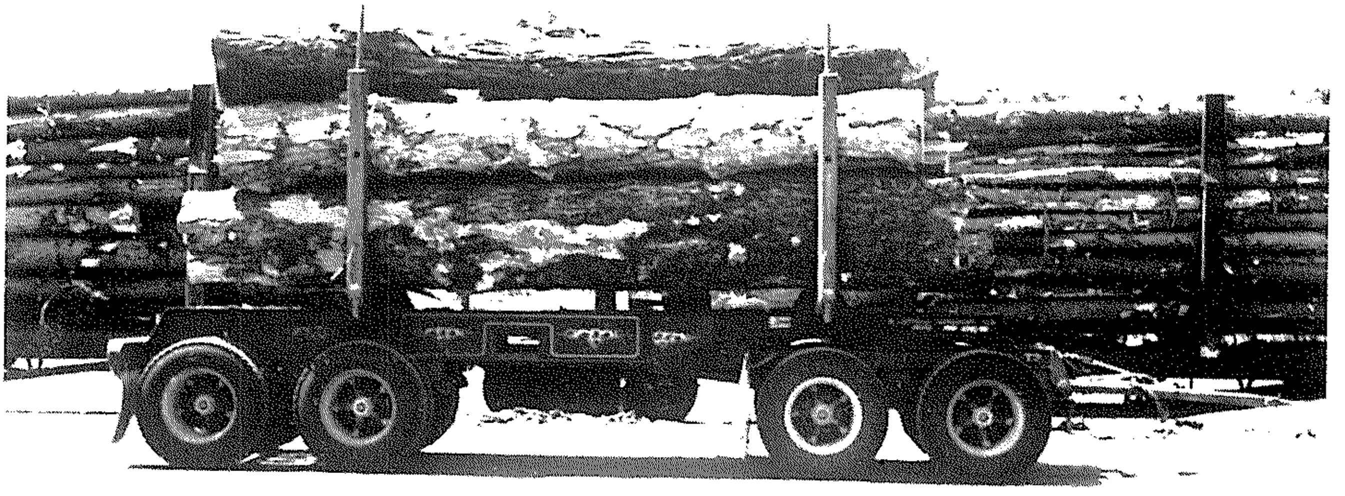
The towing unit in each case was a 283 kw 8 x 4 truck fitted with a DZL 115TC fuel flow metre to measure fuel consumption.

The objective of the trial was to determine the relative fuel efficiencies of the three different tyre types.

PROJECT DESCRIPTION

TRAILER AND TYRE SPECIFICATIONS

Brightwell : Standard dual radial tyres



Tyre Type	:	11R22.5 Radial
Tyre Pressure	:	90 - 95 psi
New Tyre Cost	:	$445.00
Recap Tyre Cost	:	$225.00
No. of Tyres on Trailer	:	16
Trailer Tare Weight	:	5480 kg
Payload on Trailer	:	17230 kg
Gross trailer weight	:	22710 kg

11R22.5 Radial Tyre Characteristics

Advantages

- readily available
- proven track record in bush operations
- specialised logging treads have been designed for this tyre size
- proven casing life with more capability for retreading
- cheaper retreading costs
- one spare required for whole unit

Disadvantages

- inside punctures difficult to detect
- heavier unit weight (dual set)
- greater risk of damage

Medlicott : Super-Single tyres

Tyre Type	:	Super-Single
Tyre Pressure	:	85 psi
New Tyre Cost	:	$669.00
Recap Tyre Cost	:	$250.00
No. of Tyres on Trailer	:	8
Trailer Tare Weight	:	4520 kg
Payload on Trailer	:	17230 kg
Gross trailer weight	:	21750 kg

Super-Single Tyre Characteristics

Advantages

- lowers centre of gravity slightly
- improved mileage based on Medlicott's experience and overseas data
- widens spring centre locations, improving stability
- one super-single tyre and rim is significantly lighter than two 11R22.5 radial tyres and rims. This weight discrepancy is even greater when using aluminium rims - increased payload capacity.
- less tyre maintenance problems - i.e. rocks etc. cannot become wedged between dual sets
- improved braking - increased brake drum clearance
- less mud carried onto highway
- super-single tyres are wider in relation to height 10 aspect ratio of 65. This wider tread improves trailer stability.
- Wheel and tyre maintenance reduced. Instead of maintaining 16 tyres, only eight tyres need maintenance.

Disadvantages

- heavier unit weight to lift when tyre changing
- reduction in allowable gross load per axle under new weight laws from 8.2 to 7.2 tonnes.
- expensive to convert existing trailers to run on super-single tyres
- increased road tax cost per axle
- the increase in weight per area of rubber in contact with the road causes super-singles to "sink" in soft or muddy conditions.

Dicker : Low Profile Tyres

Tyre Type	:	22570/22.5 Low Profile
Tyre Pressure	:	90 - 95 psi
New Tyre Cost	:	$530.00
Recap Tyre Cost	:	$225.00
No. of Tyres on Trailer	:	16
Trailer Tare Weight	:	5980 kg
Payload on Trailer	:	17230 kg
Gross trailer weight	:	23210 kg

Low Profile Tyre Characteristics

Advantages

- Tyres are smaller and lighter (6 kg lighter per tyre)
- less rolling resistance as lower aspect ratio reduces scrubbing in tread contact area
- longer tread life because lower aspect ratio reduces tread scrubbing due to shorter sidewalls and longer tread contact area
- trailer centre of gravity lowered by up to 10 cm
- shorter sidewalls and wider belts reduce tyre deformation during cornering
- same load carrying capacity of an 11R22.5 radial tyre
- improved stability because of shorter sidewalls
- shorter sidewalls reduce rolling resistance because of less sidewall flexing

Disadvantages

- more suited to on-highway operating. Some logging contractors have encountered premature wear and excessive chipping on logging roads; this is particularly evident with inferior brands.
- increased wheel bearing wear
- rocks and other debris can cause severe damage when wedged between dual sets
- can affect brake performance, balance and wear. Poor brake balance will increase tyre wear
- low profile tyres do not absorb road irregularities as well as conventional radials

ENGINE AND TRUCK PERFORMANCE

A preliminary trial highlighted the need to test the relative fuel efficiencies of the three different types of tyre while the pulling unit's engine was under load and working close to its maximum torque.

Truck engines are seldom run at their rated maximum speed. In fact they are usually operated at maximum torque or at the speed where fuel consumption is least. In climbing hills, there may be occasions when the engine revs are raised to maximum to produce maximum horsepower. However the most efficient method of operation is to use the rpm range which maximises torque.

If an engine's rpm range, at which maximum torque is produced is extremely narrow then a slight increase in rpm above, or decrease below, the maximum torque range will cause a substantial loss of power. This is a poor performance characteristic. The Cummins Super E380 engine (Appendix II) used in this trial had a relatively broad, flat torque curve so any minor deviation from peak torque during the trial did not greatly affect the fuel efficiency of the engine and the accuracy of the results.

The 1988 Cummins engine used in the trial had been serviced regularly throughout its life and was in peak condition. The engine had travelled approximately 110,000 km with no major problems.

Figure 2 is the performance graph for the engine. The torque values on the vertical axis, range from approximately 1400 Nm to 1650 Nm. As the engine revs increase from 1000 rpm the torque curve describes a convex curve. The curve flattens out between 1200 and 1400 rpm. Maximum torque is obtained at around 1300 rpm. Throughout the trial the operator was instructed to maintain 6th gear and 1400 rpm which is very close to maximum torque for this engine.

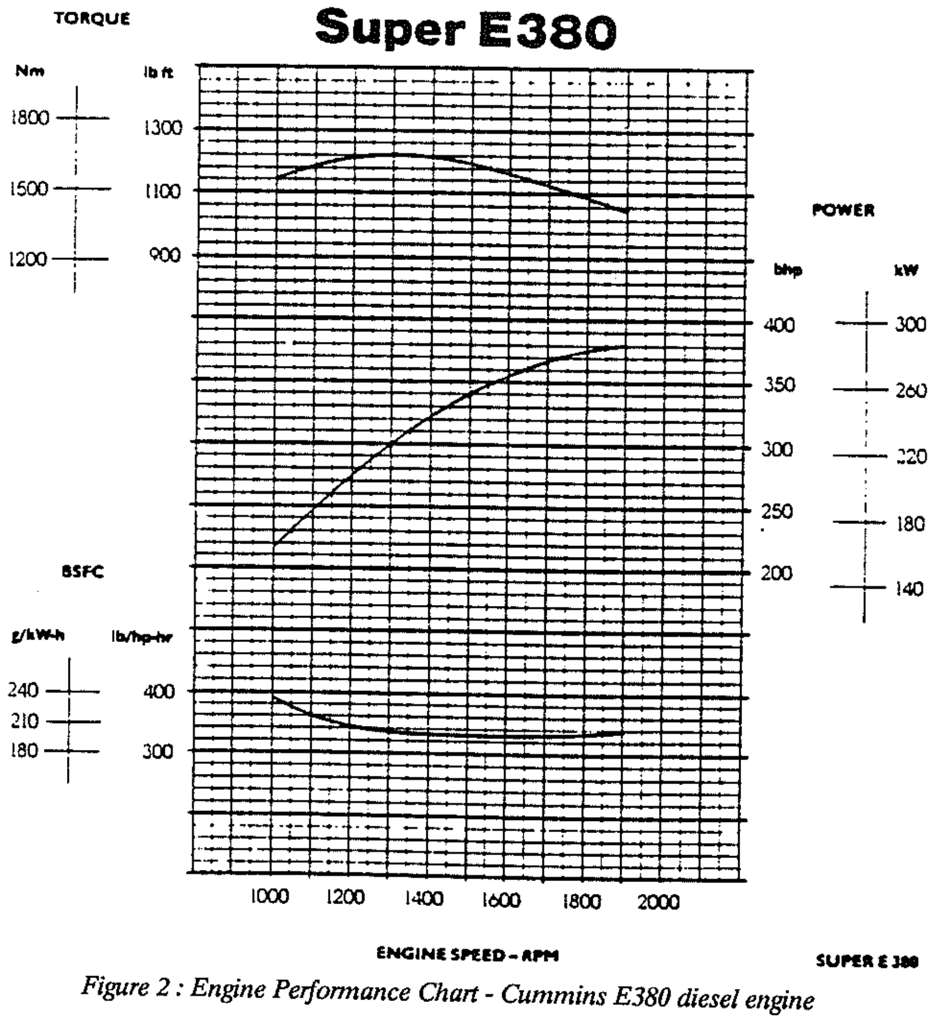


Figure 2 : Engine Performance Chart - Cummins E380 diesel engine

FACTORS AFFECTING FUEL CONSUMPTION IN LOG TRANSPORT

When transporting logs by truck, a number of resistances which have a direct effect on fuel consumption, must be overcome. The major components are:

1. The rotation resistance of a truck's drive train, which is affected by applied torque, oil type and temperature, physical condition etc.

2. Wheel and tyre rolling resistance, which is determined by inflation pressure, temperature, applied weight, road surface, bearing friction and wheel windage.

3. The air resistance as determined by vehicle speed, frontal area, air temperature and humidity.

4. Gradient resistance.

Aerodynamic drag is a function of the frontal area and shape of the truck. Wheel windage, bearing friction and suspension type are all areas that have received a lot of research and development time and money.

Tyre rolling resistance and road surface resistance are areas in which most sources fail to agree. The matter of tyre and road interaction is complex and requires consideration of the energy dissipated in tread squirm, carcase deflection, destruction of momentum by pothole impact, wheel rebound and tyre scuffing etc. One consistent finding that has emerged in recent years is that radial ply tyres have less rolling resistance than crossply tyres and many steel wire belted tyres may have even less. Therefore, for high mileage main road vehicles radial ply and steel belted tyres in particular are the preferred option, not only for their reduced rolling resistance but their increased tread life and better retreadability.

This trial was therefore designed to better understand the relative degree of fuel efficiency that exists within the greater radial tyre category. The first priority was to find out whether or not there was any difference between the three types of tyre and if so, to further research and discuss the individual merits of each tyre type with regard to working at maximum Gross Vehicle Weight in a logging environment. Furthermore it was recognised that a standard approach to each trial was necessary, i.e. one that minimised any driver influence and outside interference such as variations in ambient temperature and wind conditions. The energy required to overcome aerodynamic drag was also a major consideration when determining trial speed.

THE FUEL CONSUMPTION MEASURING SYSTEM

The towing unit used in the trial was an 8 x 4 shorts truck owned by Dave Medlicott of Rotorua. The truck is contracted to Tasman Forestry and carts short logs around the Bay of Plenty region.

Medlicott, a log transport contractor with many years of experience, has fitted the fuel tank on this unit into the truck cab guard, to avoid the damage chassis-mounted fuel tanks can suffer from loaders and falling logs. To also stop the engine 'hydrauliking' which is a possibility with a low pressure fuel system and the fuel tank at least one metre higher than the engine, Medlicott incorporated a small header tank, down low and prior to the fuel pump. DZL 115TC fuel flow metres can be fitted in two ways. For engines such as Detroits that utilise unit injectors and require excess fuel at the injectors for cooling, it is necessary to metre the fuel both to the injectors and returning to the tank. The other system, which is more accurate and is the system used in this trial, incorporates a small vacuum float tank in the fuel circuit and simply metres the fuel demanded by the engine from the bottom of the vacuum float tank (See Appendix III).

The fuel flow metre was connected in the fuel supply line prior to the vacuum float tank and after the primary filter. An extra filter was fitted prior to the metre to ensure no dirt or impurities could enter the metre and either jam it completely or affect its accuracy. The metre was installed with the toggle valve down to ensure automatic air

Figure 3 : Showing vacuum float tank bolted to front of cab guard to ensure fuel temperature stabilisation.

purge. The heated fuel returning from the injectors feeds back into the vacuum float tank where its temperature is stabilised through the design of the tank and its prominent mounting position on the front of the cab guard (see Figure 3).

The information from the fuel metre was sent via a specially built interface to a Husky Hunter portable data logger. The Husky Hunter allowed the fuel flow to be scanned every second and for the data from the trial to be down loaded onto a computer and further analysed.

PRELIMINARY TRIAL

In November 1988 a preliminary trial was conducted on a section of sealed private road near Murupara. The preliminary trial was conducted for two main reasons.

The first was to highlight any areas that were likely to have an effect on the accuracy of the results. More specifically the preliminary trial enabled us to:

- determine the accuracy of the metreing equipment and become fully conversant with its operation.
- determine the optimum scan period of the Husky Hunter in relation to its memory capacity
- assess the operator's ability and the likely effect he would have on the results
- determine the degree of influence the trial site would have on the results and their accuracy.

The second reason for conducting a preliminary trial was to determine whether there was a significant difference in the

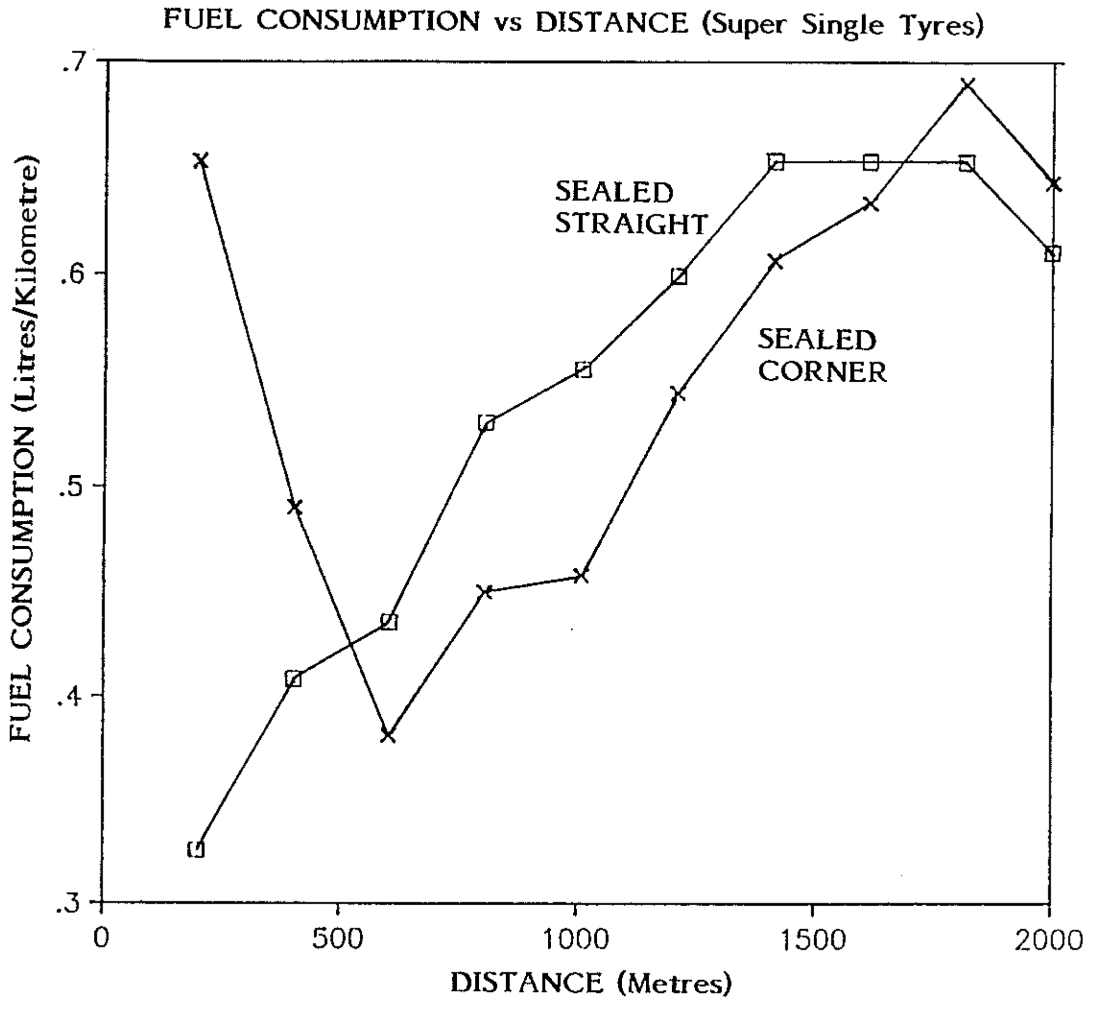


Figure 4 : Results from comparison of fuel consumed when cornering and travelling on straight sealed highway.

fuel consumed by the towing unit when towing a trailer around a corner or along a straight section highway.

In 1988 Yves Provencher, a transport researcher from FERIC, carried out a study to examine the effect of increasing axle spacings on fuel consumption. He noted that the fuel consumption increased by 4.5% when the axle spacing was increased from 4.21 m to 6.03 m. Further trials revealed that the fuel consumption of a quad-axle semi-trailer spaced at 6.03 m could be 4% less if two steering axles were installed. His results also showed that wider axle spacings have a greater effect on fuel consumption when travelling on sealed highway than on gravel. This may result from the fact that the lateral resistance when cornering on ashphalt is likely to be higher since the tyres are less prone to side slip on such surfaces.

More specifically the preliminary trial was designed to see whether the DZL metreing equipment was accurate enough to detect any change in fuel consumption while cornering and whether the different characteristics of the tyre designs and their relative spacings were enough to create a significant difference.

The results were far from conclusive (Figure 4) and it was decided to simply trial the trailers under controlled conditions on straight sealed highway.

TEST PROCEDURE

To determine the relative fuel efficiencies of low profile, super-single and 11R22.5 radial tyres used in logging, three four axle short log trailers each with different tyre types were loaded with the same payload and taken three times each over the same pre-analysed section of highway.

Taking the information gained from the preliminary trial into account, a 4km section of straight sealed highway near Murupara was selected to test the relative fuel efficiencies of the three different types of tyre. The trial section had a continuous 2.5% uphill grade, with only minor deviations, over the 4 kilometre distance. Therefore the results gained from this trial pertain to straight sealed highway running. The relative effect on fuel consumption of cornering and off-highway running were not measured. The adverse grade also allowed the engine to be run under reasonably steady load with minimal driver influence.

The trial of the three trailers, which took approximately $4^1/_2$ hours to complete, took place on an overcast Sunday in April. Throughout the trial, wind, ambient temperature and road condition and temperature were monitored and remained constant. The ambient temperature was 19^0C and there was no wind movement.

The towing unit to which the DZL fuel metreing equipment was fitted and the trailer with the super-single tyres were based in Rotorua. The trailers with the 11R22.5 standard tyres and the low profile tyres respectively were both based in Taupo. Prior to the trial starting at approximately 12.30 pm the towing unit had travelled from Rotorua to Taupo via State Highway 5 to collect the other two trailers and back to Murupara via the low level off-highway road through Kaingaroa Forest. At the commencement of the trial the gearbox, differential and engine oils were all at their optimum operating temperatures.

The 8 x 4 towing unit chosen was considered to be a typical short log truck as far as power and power to weight ratio are concerned. 8 x 4 trucks are also the most economic way to transport logs under the new weights and dimensions legislation so this configuration was deemed to be at the forefront of log transport both now and in the future.

The fuel consumption tests of the three different four-axle shorts logging trailers were each done separately. The towing unit was loaded with a payload of 11490 kg. The first trailer tested had 11R22.5 radial tyres and was loaded with a payload of 17230 kg. This same payload was transferred to the other two trailers and the payload on the towing unit was left unchanged. The payloads were weighed by on-board electronic scales which have been shown to be accurate to within 2% throughout their service life. Tyre pressures were checked prior to each test and were kept uniform as recommended by the tyre manufacturers.

A detailed procedure of the fuel consumption test is as follows:

1. The fuel metreing programme (LIRA.HBA) was loaded into the Husky Hunter data logger. By striking any button the Husky would start logging the data from the fuel metre.

2. Prior to the start of the 4 km test section the driver accelerated the truck to the desired pre-determined road speed by selecting 6th gear and maintaining 1400 rpm.

3. As the towing unit passed the marker indicating the start of the 4 km test section, the Husky Hunter was activated and began logging the data from the DZL fuel metre.

4. The driver maintained 1400 rpm throughout the 4 km test section.

5. As the towing unit passed the mark indicating the end of the 4km test section the Husky Hunter was stopped and reset to receive data from the next trial.

6. After trials 3, 6 and 9 the towing unit and trailer returned to the Murupara railyard where a log stacker transferred the payload from one trailer to the next.

7. The fuel consumption data in the Husky was downloaded onto a PC and analysed at a later date.

RESULTS AND DISCUSSION

FUEL CONSUMPTION

The time taken, fuel temperature and total fuel consumed for each trial are summarised in Table 1.

Table 1 indicates that the trial design and its application were good in both instances. The small range of results strongly support the need for detailed trial design and where possible a preliminary trial. The ability of the operator to concentrate for relatively long periods of time in maintaining the required engine speed is another factor that adds to the quality of the results.

Table 1 : Summary of results of fuel consumption trials

Brightwell Trailer (11R22.5 radial tyres)	Trial 1	Trial 2	Trial 3	Average
Total Time (seconds)	434	434	435	434.3
Total Fuel Consumed (litres)	5.757	5.757	5.691	5.735
Temperature Variation	35 - 37^{0}C	36 - 39^{0}C	36 - 38^{0}C	

Medlicott Trailer (Super-Single Tyres)	Trial 4	Trial 5	Trial 6	Average
Total Time (seconds)	430	433	434	432.3
Total Fuel Consumed (litres)	5.461	5.461	5.461	5.461
Fuel Temperature Variation	35 - 36^{0}C	37 - 38^{0}C	37 - 39^{0}C	

Dicker Trailer (Low Profile Tyres)	Trial 7	Trial 8	Trial 9	Average
Total Time (seconds)	434	434	432	433.3
Total Fuel Consumed (litres)	5.757	5.691	5.724	5.724
Fuel Temperature Variation	36 - 37^{0}C	38 - 40^{0}C	38 - 40^{0}C	

The small variation in trial times increases the significance of the difference between the fuel consumed per trailer. This small percentage change in time and therefore speed per trial indicates that the majority of the charge in fuel consumed per trailer was due to either the variation in gross weight of each trailer or the rolling resistance of the tyres. There is only five seconds difference between the fastest trial, trial 4 and the slowest trial, trial 3. The mean time for the nine trials was 433.3 seconds, indicating the degree of driver influence causing error throughout the nine trials was approximately 1.1%.

Fuel temperature fluctuated between 35^{0}C and 40^{0}C throughout the trials. The DZL fuel metre automatically compensates for any fluctuation in fuel temperature, however the smaller the fluctuations the higher the accuracy of results.

The minute change in fuel consumed by the towing unit over the three trials per trailer suggests little to no error due to outside influences occurring while trialing the same trailer.

In trials 1 to 3, Brightwell's trailer on 11R22.5 radial tyres, the fuel consumption fluctuated by 1.1%. In trials 4 to 6, Medlicott's trailer on super-single tyres, there was no fluctuation in fuel consumption, and in trials 7 to 9, Dicker's trailer on low profile tyres, the fuel consumption fluctuated again by 1.1%.

Obviously in fuel consumption tests such as these, unexplained errors are inevitable and closer analysis of trials 4 to 6 highlights this fact. While the fuel consumption over these three trials did not vary at all, the time taken to complete the three runs varied by .9%. While errors of this magnitude are not significant in terms of the overall result, an explanation of their source is difficult.

The preliminary trial highlighted the need to have a test route of constant gradient to:

1. make it easier for the driver to maintain the required engine speed

2. enable the trial to be conducted with the engine under load and working close to its peak torque and thus fuel efficiency without an increasing vehicle speed. When the vehicle speed goes above 45 - 50 km/hr (Figure 5) the fuel consumption emphasis shifts from tyre rolling resistance to aerodynamic drag.

Figure 5 also shows that rolling resistance is affected very little by road speed. However the three trailers were all tested at the same constant speed and not over a range of speeds.

Figure 6 compares individual trailer performance. These results, which are not adjusted for GVW, show what advantage Medlicott has over competing operators by:

1. using super-single tyres

2. operating a trailer with a low Tare weight. A simple comparison of the three similar trailers shows Medlicott's trailer to be 7% more fuel efficient than the other two when carrying the same payload.

Trials 2, 6 and 8 were selected for more detailed analysis because exactly the same time (434 seconds) was recorded to travel the 4 km test route with the three different trailers. The results (Figure 7) have been presented on a litres/kilometre-tonne to cancel the difference in gross vehicle weight between trials 2, 6 and 8 i.e. the difference in trailer Tare weight.

Figure 8 shows that initially the fuel consumed/kilometre drops suddenly over the first 500 m before settling down. This occurs because the fuel metreing programme in the Husky Hunter operates on an averaging system and it requires a number of readings before the programme 'settles down'.

One adverse effect of trialling the three trailers over an inclined route at low speed was that in one trial there wasn't sufficient airflow to maintain constant engine temperature. This resulted in a sudden jump in fuel consumption (Figure 9 - low profile tyres) from approximately 1400m to 1600m when the fan cut in. The fan stayed engaged for approximately 49 seconds. This had no effect on the driver's ability to maintain constant engine speed but had a small effect on fuel consumption.

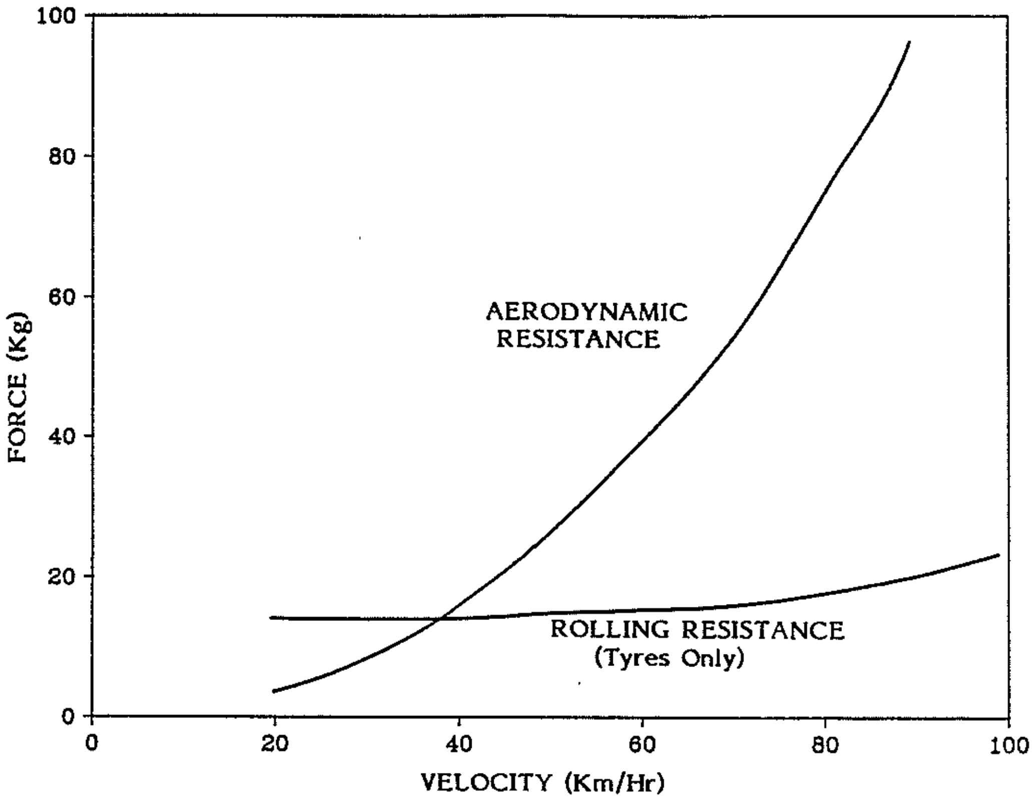


Figure 5 : Rolling and Aerodynamic resistance as a function of speed

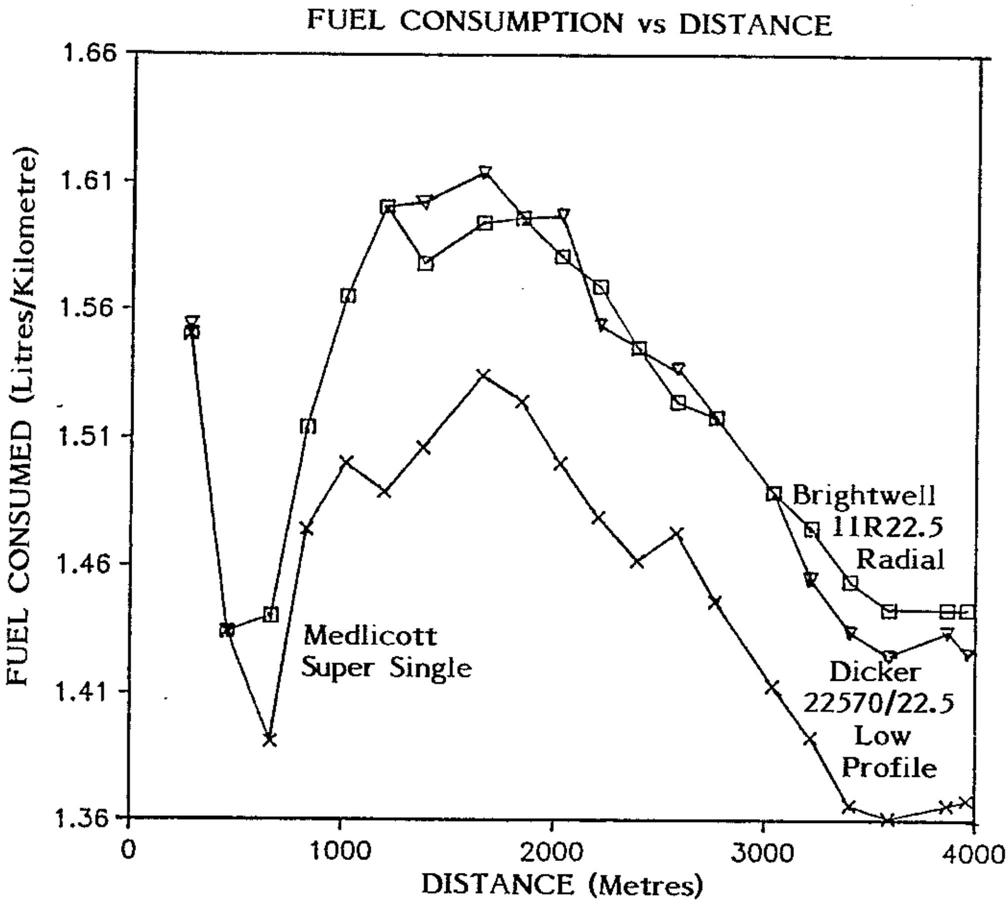


Figure 6 : Individual trailer performance. Results not adjusted for gross weight.

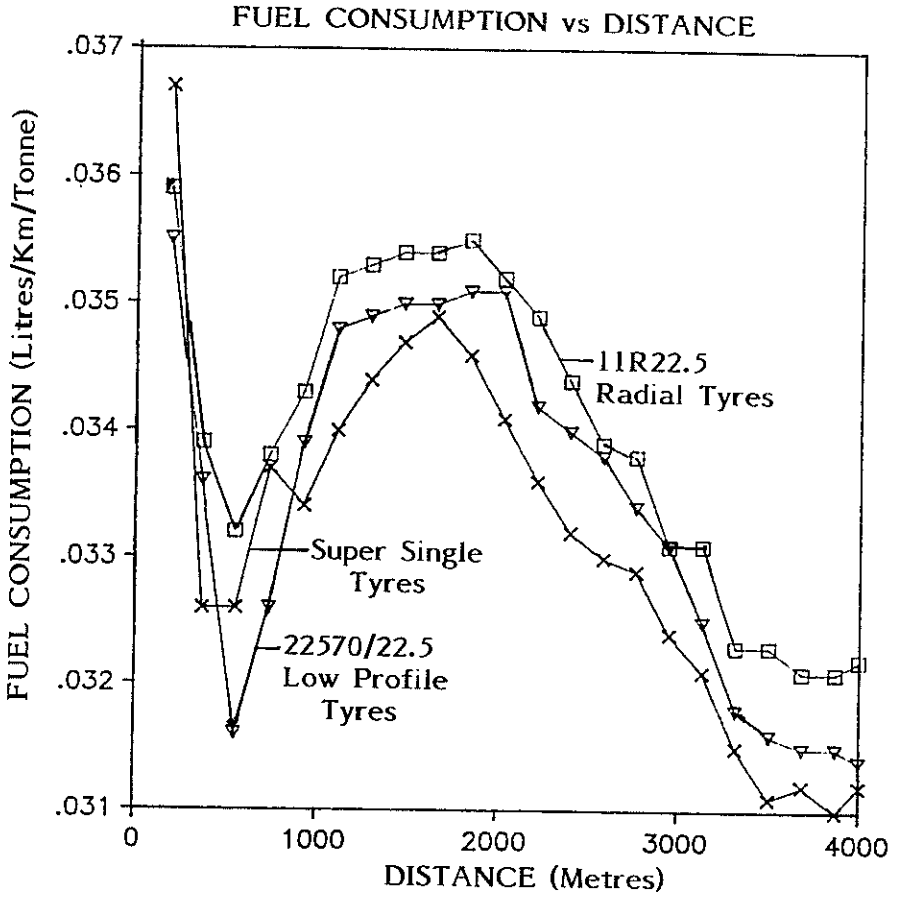


Figure 7 : Comparison of relative fuel efficiency of tyres. Results adjusted for GVW.

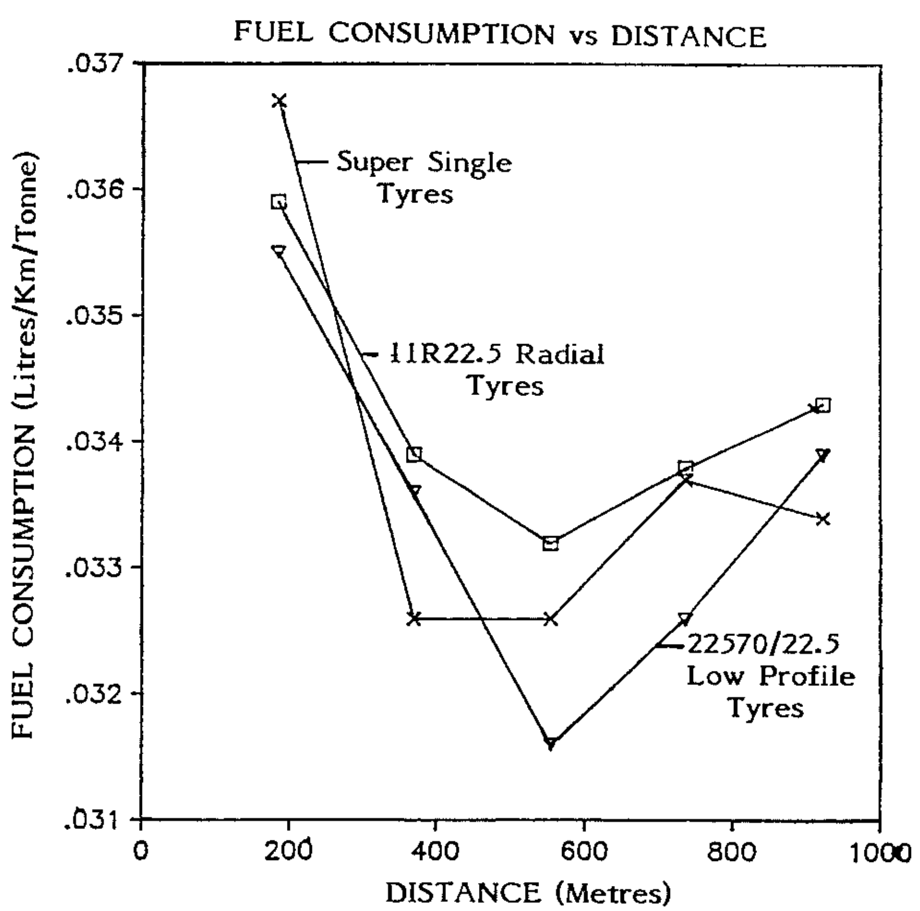


Figure 8 : Fuel consumped/kilometre drops initially while the Husky Hunter settles down.

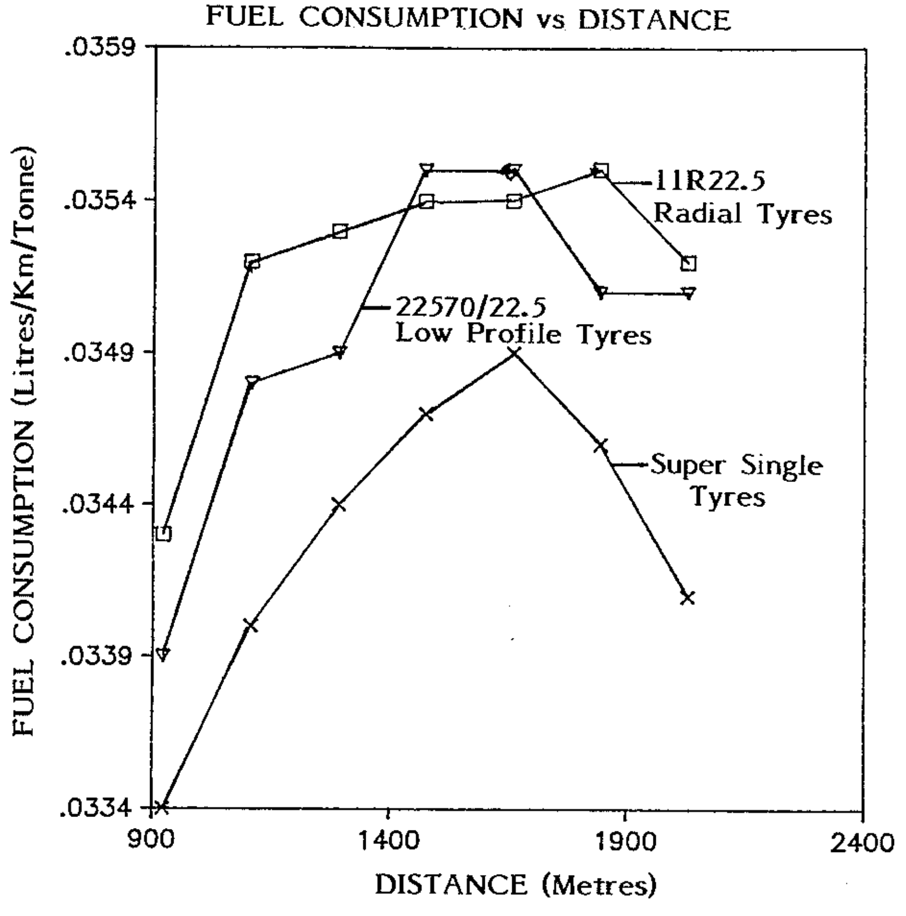


Figure 9 : Graph showing engine for clutch cutting in at approximately 1400 m.

Overall however, the relative similarity of slope of all three lines indicates good experimental design and constant conditions for each trial.

A mathematical equation to predict the fuel consumed by a loaded truck on a sealed grade (Appendix I) was used to calculate theoretical consumption, as a comparison with the trial results.

For a 43.9 tonne rig on the test grade, predicted fuel consumption is <u>5.84 litres</u>. This corresponds closely with the actual test results range of 5.46 to 5.76 litres.

This equation shows that fuel consumption is not directly proportional to gross vehicle weight. For example a 1 tonne (2.3%) increase in GVW to 44.9 tonnes gives a predicted fuel consumption increase of only 1.3%.
We can use this equation to adjust the average results of the three trials for each specific GVW. However it is not fair to fully adjust the super-single tyre trailer by the full one tonne difference in tare, as nearly half of this weight saving is an inherent advantage of super-single tyres (100kg per axle x 4 axles = 400 kg). Therefore the fuel consumption is adjusted for only 600 kg of weight difference in the trailer itself. Low profile tyres are lighter too but not enough to consider in this comparison.

The comparative fuel consumptions adjusted for gross vehicle weight are shown in Table 2.

Therefore it can be seen that the trailer fitted with super-singles has a <u>4%</u> better fuel efficiency than standard radials. The difference between low profile and standard tyres is within the range of experimental error and not significant.

Table 2 : Fuel consumption adjusted for gross vehicle weight

Tyre Type	Fuel Consumption (l)	GVW (tonnes)	Adjusted Fuel Consumption[1] (l)	
Standard Radial	5.735	44.86	5.735	
Super-Singles	5.461	43.9	5.532	-4%
Low Profile	5.724	45.36	5.687	-1%

[1]Adjusted to tonnes GVW using equation in Appendix I.

OTHER CONSIDERATIONS

Tyre wear and condition were similar in each case which raises the question of individual durability. Reports to date regarding super-single tyres have varied. Medlicott, whose trailer was the subject of tests 4, 5 and 6 has had a good run out of the tyres. At the time of testing the trailer had travelled in excess of 80,000 km on the original tyres which were showing little sign of wear and according to Medlicott will be good for another 45 - 50,000 km. Other reports from Kinleith contractors have been less than complimentary and in some instances there has been a conscious move away from super-single tyres on trailers. One contractor using super-single tyres on a Bailey Bridge in a close spaced tri-axle configuration got less than 45,000 km out of the tyres before having to recap them. Four possible reasons for this poor performance are:

1. High proportion of travel on off-highway unsealed roads

2. an inferior brand

3. brakes set up incorrectly

4. The Bailey Bridge trailer was sprung too high at the rear, causing the trailer, when sitting on level ground, to slope towards the tractor unit. Consequently when cornering the trailer pivots on the front axle, resulting in severe tyre scuff of the back axle.

Low profile tyres are less common in logging at present. Dicker whose trailer was the subject of tests 7, 8, 9 runs two four-axle trailers, each on low profile tyres. Dicker has had a relatively trouble free run to date, however he too chose the cheaper option when purchasing and has experienced a degree of tyre chipping mainly due to incorrect brake balance.

The performance of 11R22.5 radial tyres in logging is well known and documented. These tyres are by far the most common tyre in use in log transport today. Tyre manufacturers are continually refining construction techniques and tread patterns to not only increase the fuel efficiency of this type of tyre but to also increase durability and traction qualities for working off-highway.

CONCLUSIONS

The trial to determine the relative fuel efficiencies of 11R22.5 radial tyres, super-single tyres and low profile tyres on straight sealed highway shows super-single tyres to be approximately 4% more fuel efficient than 11R22.5 radial tyres. There was no significant difference between low profile and standard radial tyres. It should be noted that while the 11R22.5 tyres had travelled a similar distance to the other two tyre types tested, they had been retreaded with a specific logging tread that was slightly deeper and more coarse. Tread depth and coarseness have a major effect on fuel efficiency and rolling resistance and it is likely that this increased tread depth would affect the results by no more than 1%.

Assuming an average logging truck travels approximately 130,000 km annually and consumes fuel at a rate of 55 l/100 km then fuel and oil account for approximately 20% of total revenue utilised. The 4% improvement in fuel efficiency associated with super-single tyres amounts to a $2000 cash saving annually.

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APPENDIX I

FUEL CONSUMPTION PREDICTION MODEL

Prediction Model

Y_3 = .113 (330.1 + 3763/V + .0796 (V^2) + .6935 (RS *W) -20.9 (FL)
+ .163 (FL^2)

Y_3 = Fuel consumption of loaded truck on sealed road (l/100 km)

V = speed of truck in km/hr

RS = vertical rise in metres/km

W = weight of truck in tonnes

Calculations:

time = 434 seconds = .12055 hrs

dist = 4 km

speed = 33.18 km/hr

Gross weight of truck = 43.9 kg

Vertical rise = 2 $^1/_2$% gradient = $\frac{1}{40}$
Vertical rise = 25 m/km

Y_3 = .113 (330.1 + $\frac{3763}{33.18}$ + .0796 $(33.18)^2$ + .6935 (25 x 43.9)

Y_3 = .113 (330.1 + 113.4 + 87.63 + 761.1)

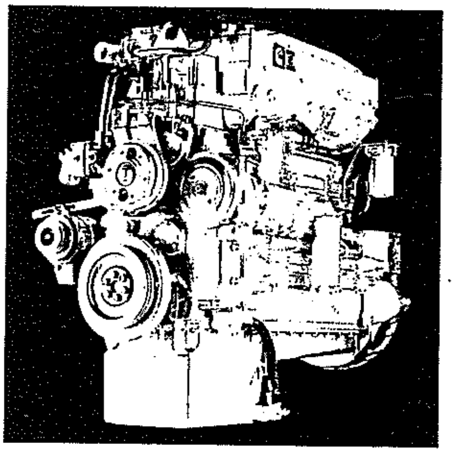
Y_3 = 146.02 l/100 km

= 1.46 l/km

Predicted fuel consumed over 4km test section = 5.84 l

SUPER E SERIES

specification



Cummins Super E Series

No. of cylinders	6
Bore and stroke	5.5 x 6in (140 x 152mm)
Piston displacement	14 litres
Compression ratio	15.0:1 (Super E320), 14.0:1 (Super E350/380/400)
Operating cycle	4
*Lube System Oil capacity	9.24 gals (42 litres)
Net weight, with Standard Accessories	All models 2650lbs (1202kg)

**Bypass filter is included in total.*

Design Features

Camshaft: Large 2½in (64mm) diameter Hi-lift camshaft controls all valve and injector movement. Induction hardened alloy steel with gear drive.

Camshaft Followers: Roller type for long cam and follower life.

Connecting Rods: Drop forged, 12in (305mm) centre to centre length. Rifle drilled for pressure lubrication of piston pin. Taper piston pin end reduces unit pressures.

Crankshaft: High tensile strength steel forging. Bearing journals are induction hardened. Fully counterweighted.

Cylinder Block: Alloy cast iron with removable, wet liners.

Cylinder Heads: Each head serves two cylinders. Drilled fuel supply and return lines. Corrosion resistant inserts on exhaust valve seats.

Fuel System: Cummins PT™ wear-compensating system with integral flyball type governor. Camshaft actuated DFF injectors.

Lubricating Oil Cooler: Tubular type two pass, water cooled, combined with spin on full flow and by pass oil filters.

Air Intake Manifold: Connected to turbocharger, contains aftercooler.

Lubrication: Force feed to all bearings, gear type pump. All lubrication lines are drilled passages, except pan to pump suction line.

Steering Pump Drive: Coupling driven, two bolt flange mounting.

Thermostat: Single unit, modulating by pass type.

Valves: Dual intake and exhaust each cylinder. Each valve 1⅞in (47mm) diameter. Heat and corrosion resistant face on exhaust valve.

Water Pump: Belt driven, centrifugal type, 94 gals (428 1/min) @ 1900rpm, with volute type housing cast in block to provide more efficient flow.

Available Equipment

Air Compressor: Cummins 13.2 CFM (374 1/min) one cylinder, coupling driven and pressure charged.

Corrosion Resistor: Spin on type, mounted. Checks rust and corrosion, controls acidity, and removes impurities from coolant.

Electrical Equipment: 12 and 24 volt starter; 12 and 24 volt alternators of various ampere outputs; and alternator mountings.

Fan: 24 in. (610mm), 26 in. (660mm) or 28 in. (711mm) diameter, sucker type.

Fan Mounting: Bracket mounted hub and pulley. Hub 12.62 in. (321mm) above crankshaft.

Filters: Lubricating oil, full flow and by pass paper element, spin on types mounted in combination with oil cooler.

Flywheel: For 15.5 in (394mm) 2 plate clutch to fit various automotive clutches.

Flywheel Housing: S A E No 1 and 2 cast aluminium with mounting pads.

Governor: Mechanical flyball, limiting speed type.

Front Mounting: Provision for pad type engine support, 6 in. (152mm) diameter trunnion.

Oil Pan: Cast aluminium, 7.5 gallon (34 litres) capacity, optional sump locations.

Turbocharger Location: Low side mounting, or rear mounting.

APPENDIX III

ERF

E14.38(

8 x 4 Four Axle Rigid

Specification

MODEL DESIGNATION
68CU38OE

ENGINE

Cummins NTE-380 Turbocharged and aftercooled
284 kW (380 bhp) at 1900 rpm
1654 Nm (1220 lb.ft.) at 1300 rpm
6 cylinder, 14 litre
Jacobs engine brake
Dynair clutch fan drive
(Engine ratings to EEC 80-1269ECE Reg 24)

CLUTCH
Spicer twin dry plate ceramic face
394mm (15 1/2 in) self adjusting
hydraulic with pedal operated clutch
brake

TRANSMISSION
Fuller Roadranger RT14715
9 speed, twin countershaft, multi-mesh

GEAR RATIOS

Speed	Ratio	
1st	9.96	15.52
2nd	7.63	11.89
3rd	5.9	9.19
4th	4.54	7.08
5th	3.57	5.56
6th	2.79	
7th	2.4	
8th	1.65	
9th	1.27	
10th	1.0	

DRIVESHAFT
Tubular shaft with needle roller bearing universal cross joints (1810 Series) with Glidecote splines

FRONT AXLES
Kirkstall model S62, 6500 kg capacity each

REAR AXLES
Rockwell SSHD single reduction tandem axles with inter-axle differential lock.
20000 kg capacity. Ratio 3.9

SUSPENSION
Front axles: Multi leaf 1524mm x 89mm wide springs.
Rear bogie: Hendrickson RTA 380. 20000 kg capacity on highway
Hydraulic telescopic dampers on front axles and rear of rear bogie

BRAKES
Full air, dual circuit in compliance with the requirements of the EEC. Air is supplied by a 374 litre/min direct gear driven compressor. A Westinghouse air dryer is standard equipment. Aluminium reservoirs.
Chambers: Type 24 on all axles
Two line trailer brake system fitted

BRAKE DIMENSIONS
Front axles 394mm x 180mm (15 ½ x 7 in)
Rear axles 420mm x 180mm (16 ½ x 7 in)
Total brake lining area 10656 cm^2

WHEELS AND TYRES
One piece welded disc 8.25 x 22.5 x 165mm offset rims. 11.00 x 22.5 stee belt radial tubeless tyres. Spare wheel and tyre carried on winch. 10 stud wheel discs

STEERING
ZF integral hydraulic power assist steering gear with 20.2:1 ratio. ZF 2 line gear driven hydraulic pump. Steering wheel diameter 500 mm 4.75 turns lock to lock. Dampers on both tierods. Turning circle (kerb to kerb) — 22.0 metres

ELECTRICAL EQUIPMENT

24 volt insulated double pole, with bayonet plug-in harness. CAV 55 amp alternator.
2 x 12 volt batteries (140 amp hr). Chassis mounted battery master switch.
Systems protected by circuit breakers easily accessible from inside the cab.
Two rectangular quartz halogen headlamps. Roof marker lamps.

COOLING SYSTEM
Radiator core frontal area 6386 cm^2
Fan diameter 720mm, Dynair clutch fan drive
Cooling system capacity 50 litres

AIR CLEANER
Donaldson (16 in) two stage with integral cab mounted stack pipe and inlet hood

FUEL TANK
Round section alloy fuel tank 364 litres capacity (80 gallons)

FRAME
High tensile carbon manganese steel 305 x 89 x 8 mm. Bolted construction using "free fit" bolts. Yield strength — 758.4 N/mm^2 (110000 PSI)

RATINGS

Max GVM	30375 kg
Max GCM	60000 kg

Chassis unladen weight incl. fuel but excl. spare wheel and driver — 9480 kg
Maximum theoretical road speed 94 km/hr at 1900 rpm (3.9 ratio)

E14.380

8 x 4 Four Axle Rigid

CAB
Type: ERF SP4 forward control with steel subframe, hydraulic 60° tilt mechanism, compression moulded SMC replaceable panels and foam lined interior panels. Cab complete with front corner air deflectors and front under run fairing. All interior surfaces finished in matching Oregon brown.

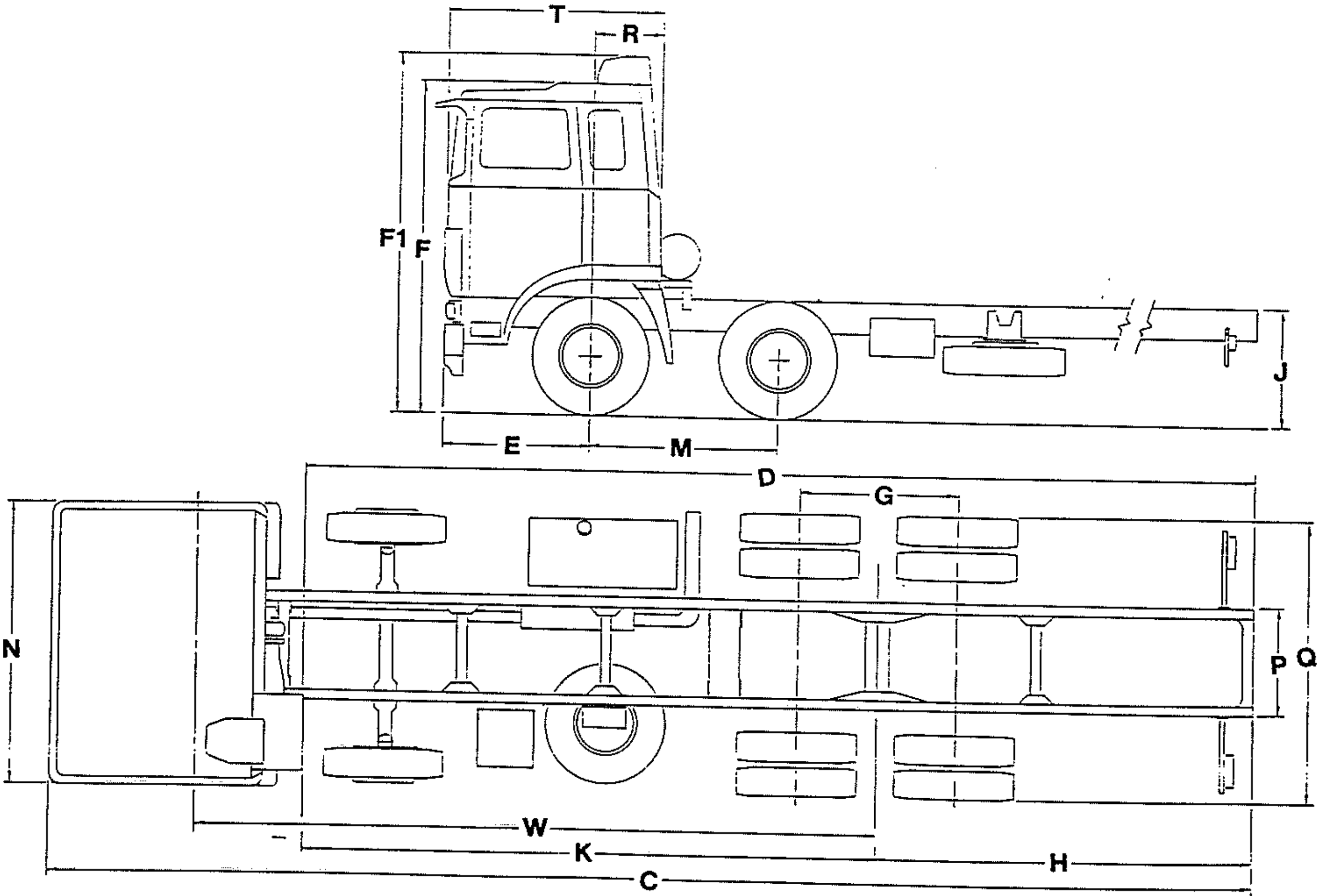
CAB SUSPENSION
Four point "Superide" system
Front — rubber spring and damper
Rear — coil spring and damper

CAB FEATURES — REST CAB
Spacious cab interior featuring "Isringhausen" high back suspension driver's seat fully adjustable for height, reach and rake. Low back adjustable passenger seat. One piece laminated windscreen, electrically heated rear view mirrors, pedestrian mirror. Two speed electric self parking wipers with screen wash, flick wipe and intermittent wipe. Roof mounted vent and directional map reading lights. Provision for storage in large compartments rear of seating, in facia panel, header shelf and door pockets. Stereo radio/cassette player and speakers fitted. Facia panel incorporates full instrumentation, park brake, cigar lighter, heater controls and cassette storage trays. Electronic speedometer. Column mounted multi-switch and facia mounted rotary light switch. Serious malfunctions monitored by flashing "STOP" warning light in display screen. Single fold down bunk and full night curtains. Dual air and electric horns. External sunvisor and windshield stoneguard.

DIMENSIONS

T	1898 mm
R	600 mm
E	1298 mm
F	2900 mm
F1	3150 mm
H	3240 mm
D*	8220 mm
K*	4990 mm
J unladen	1045 mm
C	10508 mm
N	2495 mm
P	940 mm
Q	2500 mm
M	1610 mm
G	1320 mm
W	5900 mm

* to rear of obstructions

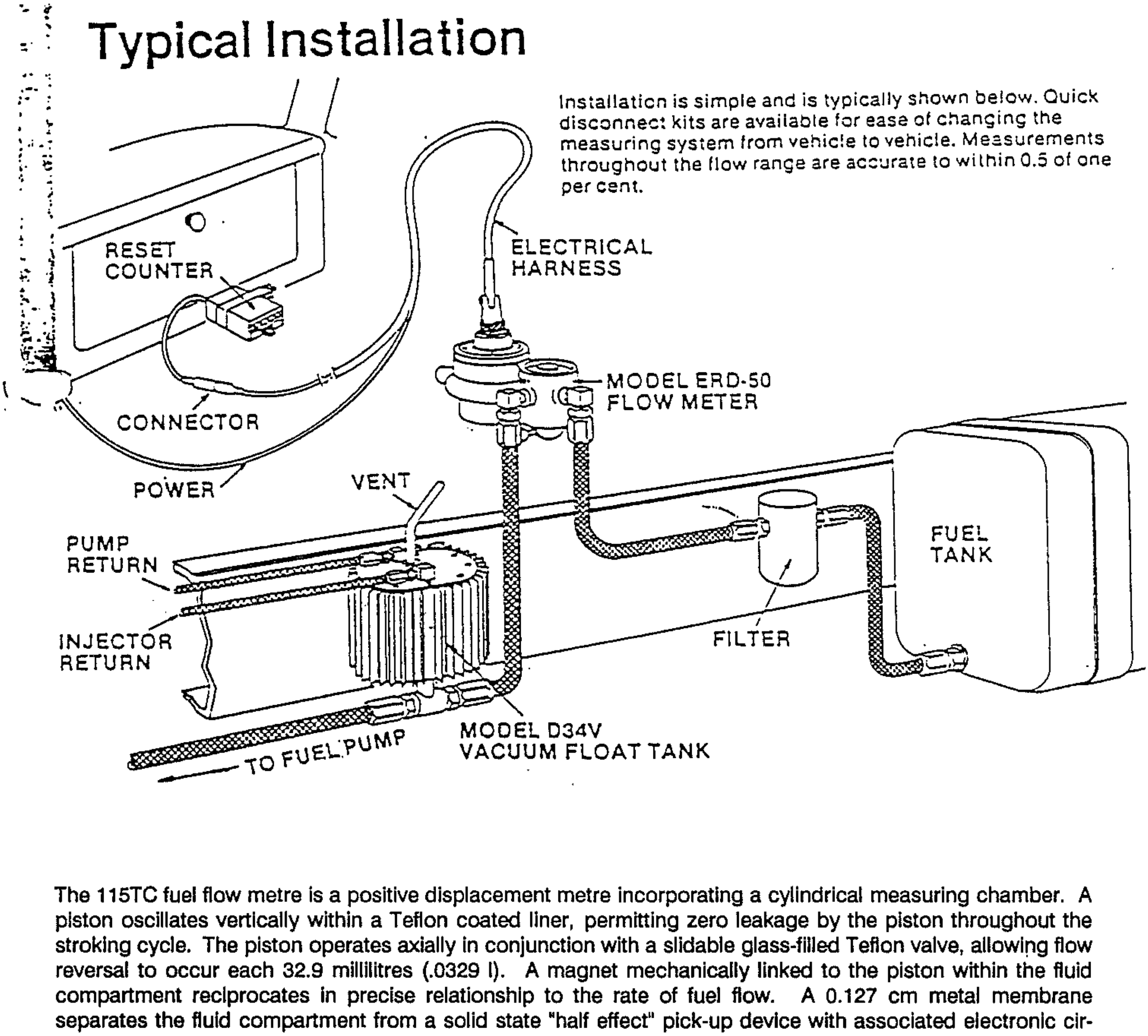


ERF retain the right to alter specifications and dimensions without prior notice.
All information is believed to be correct at the time of printing but must not be taken as binding.

August 1988

APPENDIX IV

FUEL MONITORING INSTALLATION



The 115TC fuel flow metre is a positive displacement metre incorporating a cylindrical measuring chamber. A piston oscillates vertically within a Teflon coated liner, permitting zero leakage by the piston throughout the stroking cycle. The piston operates axially in conjunction with a slidable glass-filled Teflon valve, allowing flow reversal to occur each 32.9 millilitres (.0329 l). A magnet mechanically linked to the piston within the fluid compartment reciprocates in precise relationship to the rate of fuel flow. A 0.127 cm metal membrane separates the fluid compartment from a solid state "half effect" pick-up device with associated electronic circuiting which, along with a solid state temperature sensor, are located outside the measuring chamber but within the metre housing. The pick-up device senses each magnet oscillation which represents precisely 32.9 millilitres and transfers a pulse spark to the interface and Husky Hunter where the computer compensates the pulse for fuel expansion or contraction due to temperature.