TESTING HAULAGE TRACTORS

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Abstract

This paper is a comprehensive report on tests that have been done on a range of tractors used for sugarcane haulage. The results of earlier work by Murray & Boevey,[1] as well as those of a recent programme of tests conducted on tractors with Atlantis Diesel Engines (ADE), are included. Speed, load and fuel consumption over a 23 km route with known gradients, were measured with the object of establishing a basis for comparing haulage tractors, particularly those in which gear and final drive ratios have been modified.

Introduction

The escalation in costs of road haulage has led to an investigation of the economics of using tractors as haulage units. The recently introduced ADE engines have different power and torque outputs and manufacturers have been prompted to alter the tractor's gearing in an attempt to improve performance, particularly regarding hauling ability.

Two tractors of more than 100 kW and others between 40 and 60 kW of the types usually used for hauling cane, were borrowed from manufacturers for the tests. Each tractor pulled loads varying from 5 to 30 tons over a predetermined test route from the La Mercy farm to the Mount Edgecombe sugar mill and back. Fuel consumption, mass of the load and the time taken to travel between the marker pegs for each gradient were recorded (Murray & Boevey[1]).

The particular makes of tractors used in the tests does not imply that they are preferred by the Experiment Station. Different makes of tractors have been grouped according to criteria which are used to compare individual tractors or groups of tractors (SA Sugar Association Experiment Station[2]).

Materials and Methods

The tarred road from the La Mercy farm to Mount Edgecombe provided a route along which the tests were conducted. The road was divided into 13 parts according to gradient.

To study the effect of load on fuel consumption and to evaluate of productivity, the following criteria were used:

Gross imposed load

This is the mass of the trailers plus the ballast (rather than the nett load) which eliminates discrepancies resulting from tractors pulling trailers of different masses. The load was weighed on the weighbridge at Mount Edgecombe and where possible, bundles of cane were used as ballast. Steel blocks were used where greater mass was required.

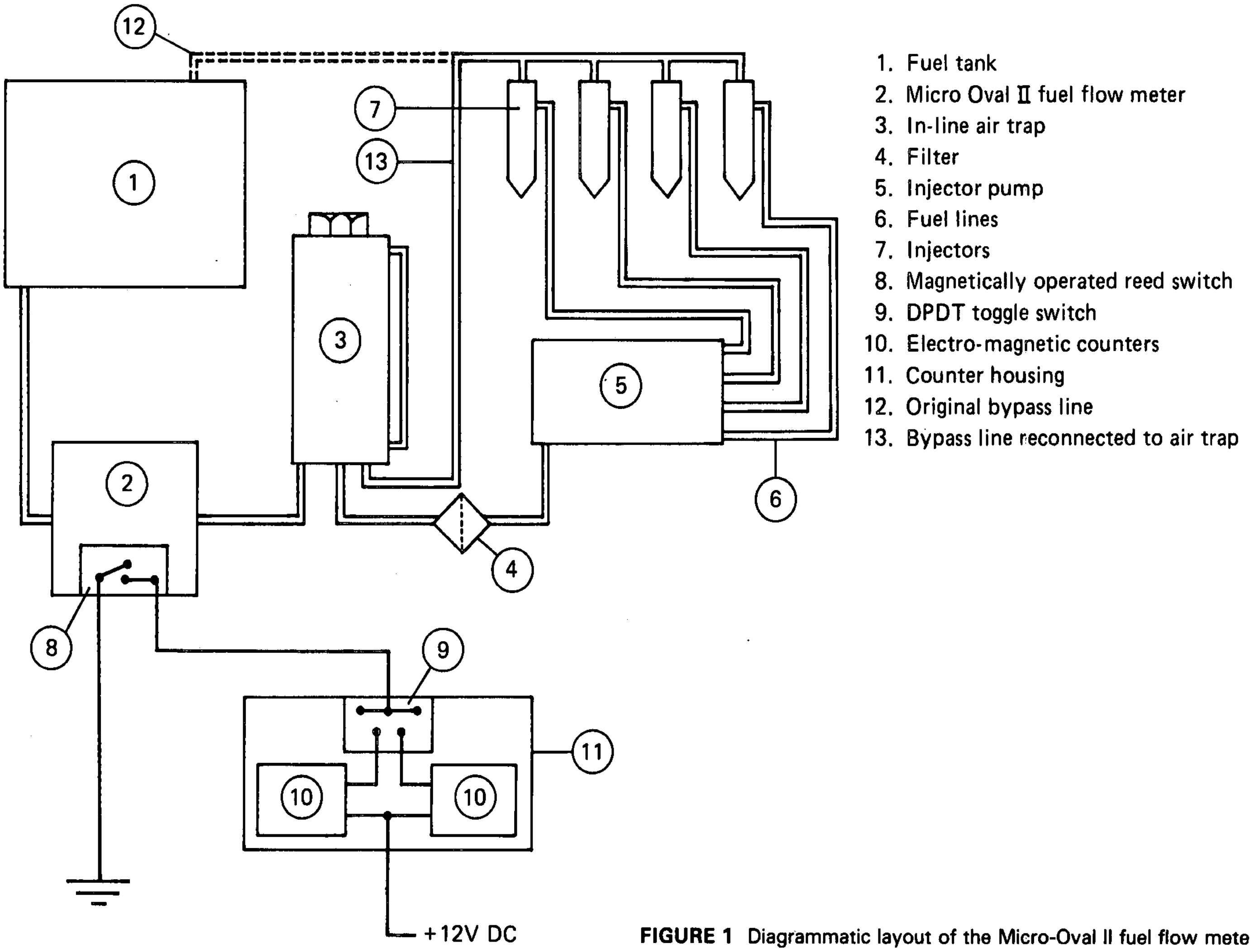

FIGURE 1 Diagrammatic layout of the Micro-Oval II fuel flow meter.

Fuel consumption

This was recorded with a Micro Oval II fuel flow meter (Figure 1) which operated an electro-mechanical counter. Two such counters were mounted in a box placed in front of the tractor driver and could be switched in sequence and reset independently. Information on the fuel consumption and speed of the tractor was relayed by citizen band radio and recorded by the passenger in a vehicle which followed the tractor.

Power determination

This was determined prior to testing the tractors on the road using a M&W P2000 pto dynamometer so that actual power output could be compared with the manufacturers' specifications. At the same time specific fuel consumption (ℓ/kWh) was determined by measuring the amount of fuel used in ml at various power levels in periods of 36 seconds to give fuel consumption in ℓ/h. Readings were taken for a number of speeds so that power and specific fuel consumption curves could be plotted. Results of a typical pto dynamometer test are given in Figure 2.

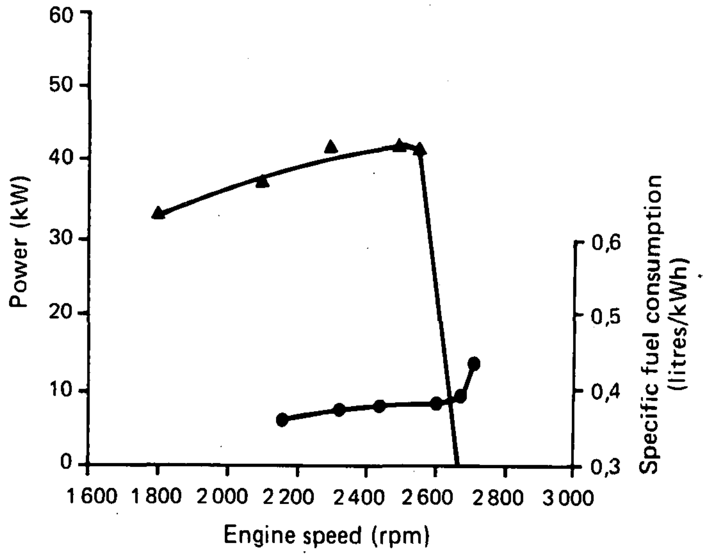

FIGURE 2 Results of a typical pto dynamometer test.

TABLE 1

Results of dynamometer tests on a range of tractors

Make of tractor and engine type	Advertised engine power (kW)	Maximum pto power (kW @ rpm)	Corresponding specific fuel consumption (ℓ/kWh)
1 Ford 56TT-ADE 236	52,0	47,1 @ 650	2,72
2 MF275 HT-ADE 236 – 12 speed	49,5	41,2 @ 620	2,64
3 MF290 HT-ADE 248	55,5	51,2 @ 630	2,91
4 Ford 5610 SP-DP-AC-ADE 236	52,0	42,7 @ 650	2,76
5 Ford 6610 SP-AC-DP-CD-ADE 236	58,0	49,8 @ 680	2,88
6 JD 2141-ADE 236T	57,0	49,7 @ 570	2,94
7 JD 1641-ADE 236	46,0	42,8 @ 610	2,56
8 Ford 5610 DP-ADE 236	52,0	39,2 @ 640	2,37
9 Ford 6610 AC-DP-ADE 236	58,0	46,7 @ 600	2,77
10 Deutz 7207-Deutz	51,2	47,3 @ 640	2,98
11 Ford TW20-Ford	107,0	104,8 @ 640	2,82
12 Ford TW25-Ford	113,0	106,1 @ 660	2,74

Note: Abbreviations used to identify tractors:

AC = altitude compensated
DP = dual power
CD = County differential
SP = special tractors (those with modified final driver ratios)
HT = haulage tractor
T = turbocharged

Speed

This is a function of the time taken to travel between two marker pegs a known distance apart. A stopwatch with a lap-time facility was used to measure the time.

Results

The results of the pto dynamometer tests and the make, engine type and modification designations of the tractors are listed in Table 1. The advertised engine power and tested pto power, together with the determined specific fuel consumption are also given.

Speed, productivity and fuel consumption for various loads and for each tractor in the road tests are given in Table 2.

TABLE 2

List of tractors tested at various loads from which fuel consumption and performance factors were calculated

Tractor	Gross imposed load (t)	Productivity (t/h)	Speed (km/h)	Fuel consumption (ℓ/h)	Fuel consumption (ℓ/tkm)	Performance (tkm/ℓ/h)	Performance (%)
Ford 56TT	5,35	8,00	34,77	11,57	0,062	24,04	63,65
	10,40	13,33	29,84	11,88	0,038	33,21	87,93
	13,40	15,22	26,41	11,92	0,034	33,72	89,28
	15,65	16,88	25,14	11,91	0,030	35,63	94,33
MF275	5,25	8,53	37,83	10,88	0,055	29,66	78,53
	10,40	13,34	29,86	11,06	0,036	36,02	95,37
	12,45	14,96	27,97	11,63	0,033	35,98	95,26
	14,90	16,74	26,12	11,58	0,030	37,76	99,97
	16,45	17,75	25,09	11,79	0,029	37,77	100,00
MF290	5,20	7,95	35,54	11,97	0,065	23,60	62,48
	10,30	13,29	30,02	12,88	0,042	30,98	82,02
	14,80	16,65	26,17	12,88	0,033	33,83	89,57
	19,60	19,68	23,35	12,96	0,028	35,46	93,88
Ford 5610SP	6,05	8,11	31,17	11,30	0,060	22,37	59,23
	8,95	10,69	27,78	11,39	0,046	26,07	69,02
	12,35	13,63	25,67	11,84	0,037	29,55	78,24
	16,85	16,39	22,62	11,97	0,031	30,97	82,00
Ford 6610SP	6,05	9,09	34,91	12,22	0,058	25,97	68,76
	11,95	14,45	28,15	12,78	0,038	31,83	83,27
	16,65	17,16	23,98	12,78	0,032	32,20	85,25
	19,25	19,33	23,36	12,84	0,029	35,17	93,12
JD2141	5,25	6,54	28,94	10,82	0,071	17,49	46,31
	10,25	11,49	26,06	10,78	0,040	27,78	73,55
	15,00	14,91	23,14	11,20	0,032	30,81	81,57
	18,30	16,88	21,46	11,21	0,029	32,31	85,54
JD1641	5,25	6,15	27,23	9,91	0,069	16,90	44,74
	7,95	8,64	25,26	10,21	0,052	21,38	56,61
	10,40	10,33	23,11	10,83	0,045	22,04	58,35
	13,75	12,50	21,14	10,77	0,037	24,54	64,97
Ford 5610	5,30	6,50	28,49	11,41	0,076	16,49	43,66
	10,30	10,94	24,71	11,37	0,044	23,78	62,96
	15,50	13,38	20,07	11,82	0,038	22,72	60,15
	21,25	15,94	17,45	12,30	0,033	22,61	59,86
Ford 6610AC	5,30	7,23	31,73	12,47	0,074	18,40	48,72
	10,40	12,42	27,76	12,56	0,044	27,45	72,68
	15,55	15,81	23,65	12,83	0,035	29,14	77,15
	20,80	18,37	20,55	13,76	0,032	27,43	72,62
Deutz 7207	5,25	5,87	25,97	8,03	0,059	18,99	50,28
	10,30	10,00	22,61	8,87	0,038	25,49	67,49
	15,25	12,94	19,73	9,23	0,031	27,66	73,23
	19,95	15,07	17,60	9,54	0,027	27,80	73,60
Ford TW20	5,25	7,68	34,00	24,49	0,137	10,98	29,07
	10,35	14,63	32,84	23,94	0,070	20,07	53,14
	22,05	26,19	27,61	23,97	0,039	30,17	79,88
	28,60	31,16	25,70	25,63	0,035	31,70	83,93
Ford TW25	5,20	7,76	34,69	22,07	0,122	12,20	32,30
	10,30	14,54	32,83	22,82	0,068	20,92	55,39
	21,20	29,57	32,42	27,42	0,040	34,96	92,56
	32,95	39,35	27,96	29,42	0,032	37,40	99,02

The effect of gradient on a 'special' tractor (Ford 56TT) and on a standard tractor (Ford 6610AC), both with ADE engines and both with the same pto power output, is shown in Figure 3. The fuel consumption in ℓ/t.km is plotted as a function of load from the data in Table 3. Raw data is smoothed using linear regression equations so that the differences become more apparent (Table 3).

TABLE 3

Regression equations of speed and specific fuel consumption for two tractors at three gradients

Tractor	Units of y	Gradient %	Regression	Correlation coefficient
Ford 56TT (47 kW)	km/h	3	y = 40,60 − 1,41 (x)	−0,99
		5	y = 34,79 − 1,45 (x)	−0,99
		8	y = 27,80 − 1,12 (x)	−0,98
	ℓ/tkm	3	y = 0,032 + 0,307(x)	−0,99*
		5	y = 0,056 + 0,290(x)	−0,99*
		8	y = 0,069 + 0,279(x)	−0,98*
Ford 6610AC (47 kW)	km/h	3	y = 34,09 − 0,95 (x)	−1,00
		5	y = 28,48 − 0,91 (x)	−0,98
		8	y = 24,07 − 0,80 (x)	−0,98
	ℓ/tkm	3	y = 0,033 + 0,363(x)	1,00*
		5	y = 0,053 + 0,358(x)	0,98*
		8	y = 0,063 + 0,339(x)	0,98*

Note: x = gross imposed load (t)
* = units of x are t^{-1}

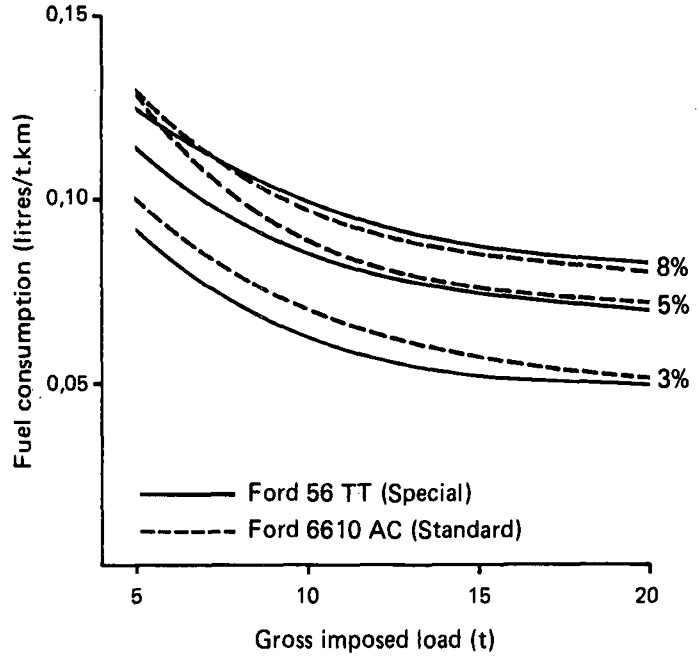

FIGURE 3 Fuel consumption vs load at three gradients for two tractors with ADE engines.

The tendency was for fuel consumption (ℓ/t.km) to decline as the load increased. The fuel consumption of the standard tractor was generally higher than that of the 'special' tractor, except at gradients of 8% for loads greater than 6,5 tons. Speed declined on all gradients as load increased (Figure 4, Table 2). The 'special' tractor (Ford 56TT), was faster than the standard (Ford 6610AC) where the gradients were 3, 5 and 8% and the loads less than 14, 11,8 and 11,5 tons respectively. The gearing of the 'special' tractor (Ford 56TT) was such that its speed had been increased at the expense of available drawbar pull (see Figure 4). The difference in speed, with increasing load and gradient, decreased until it was equal to that of the standard tractor (Ford 6610AC) at high loads. The 'special' tractor (Ford 56TT) was more fuel efficient on all gradients until the gross imposed load approached 14, 11,8 and 11,5 tons. This illustrated that a change in the tractor's final drive ratio could affect speed and fuel consumption.

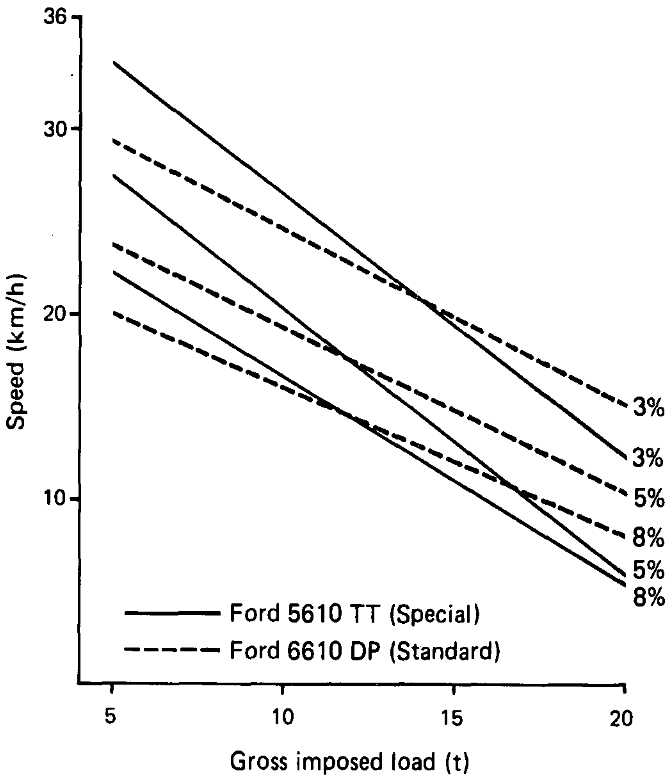

FIGURE 4 Speed vs gross imposed load at three gradients for two tractors with ADE engines.

By comparing haulage capacity and speed with load (Table 2), the performance of the tractors were rated as shown in Table 4 and in the SA Sugar Association Experiment Station's Mechanization Report 84/1.[2] The effect of rating performance can be seen in Figures 5 and 6 where productivity and speed have been plotted against gross imposed load for five different tractors.

TABLE 4

Rating of performance of tractors for speed, productivity, and specific fuel consumption, from poorest to best

Speed and productivity		Specific fuel consumption	
1	Deutz 7207	1	TW 25
2	JD1641	2	TW 20
3	Ford 5610	3	Ford 5610
4	JD2141	5	JD1641
5	Ford 5610SP	5	Ford 6610AC
6	Ford 6610AC	6	MF290HT
7	Ford 6610SP	7	Ford 5610SP
8	Ford 56TT	8	Ford 6610SP
9	MF275HT	9	JD2141
10	MF290HT	10	Ford 56TT
11	TW20	11	Deutz 7207
12	TW25	12	MF275HT

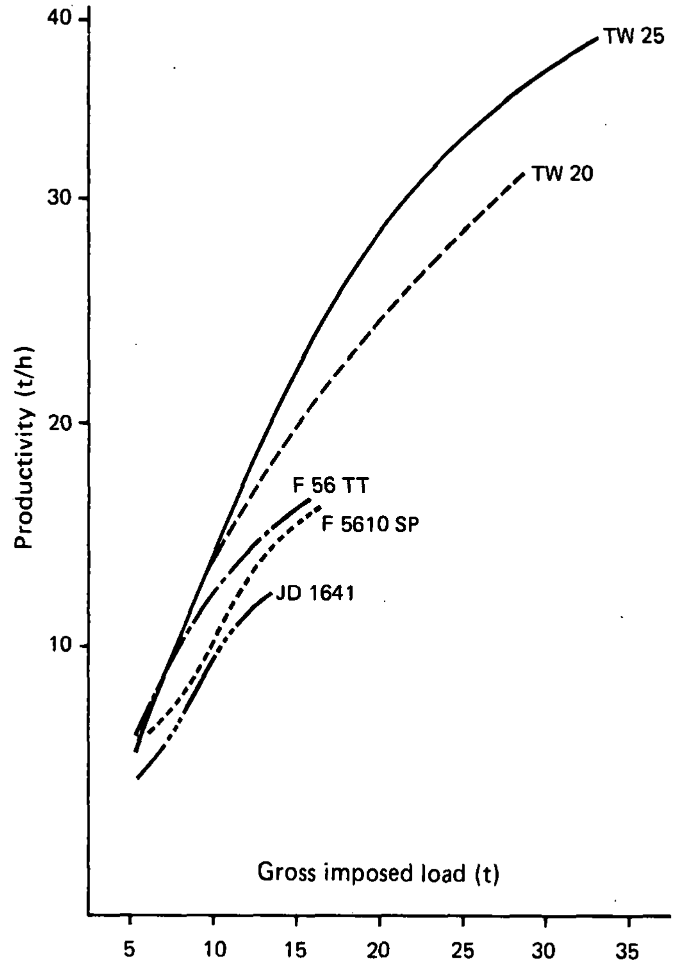

FIGURE 5 Productivity vs gross imposed load for five tractors over a 23 km route.

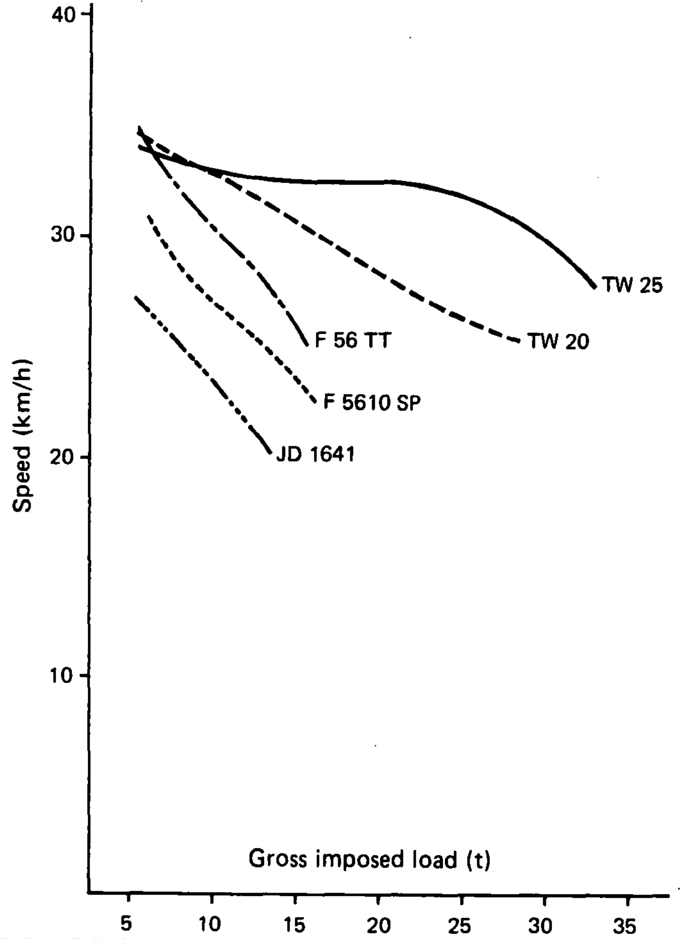

FIGURE 6 Speed vs gross imposed load for five over a 23 km route.

The fuel consumption in litres per ton km (ℓ/tkm) of a number of tractors is compared with load in Figure 7. Tractors with high, intermediate and low values (Ford 5610, Deutz 7207 and MF275 respectively) and the Ford TW's were considered. The MF275 was more fuel efficient with loads up to 16 tons (the maximum practical load on this tractor for the test route), followed by the Deutz with loads up to 20 tons. Larger tractors such as the Ford TW's were only competitive where loads exceed the capabilities of the smaller units.

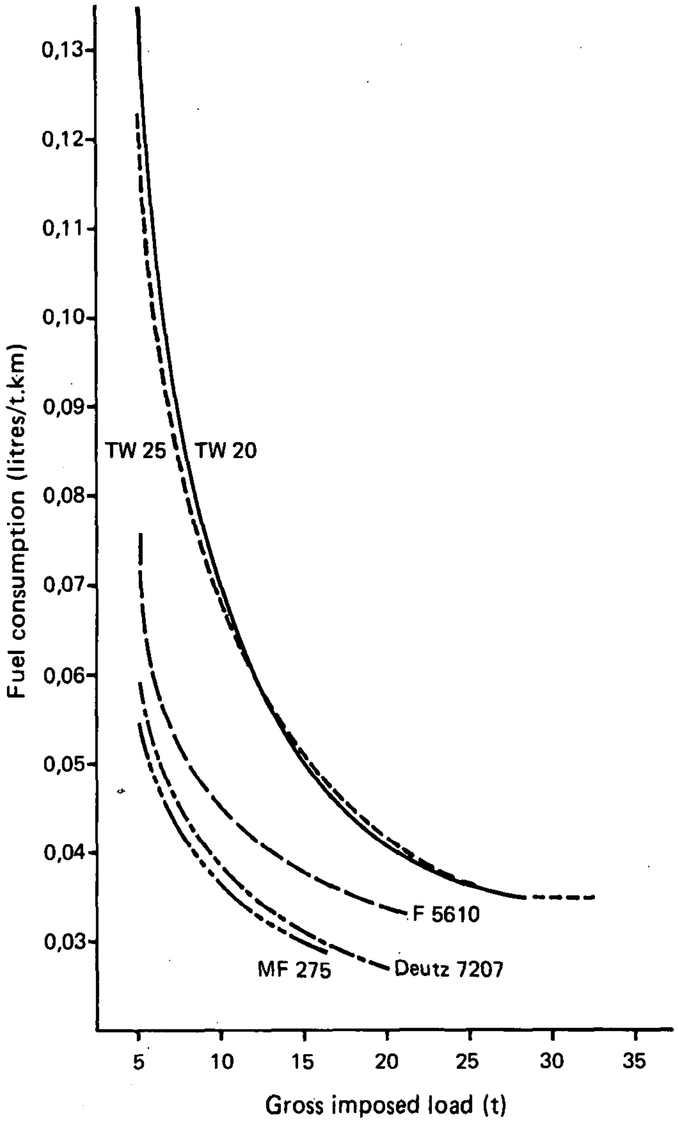

FIGURE 7 Fuel consumption vs gross imposed load for five tractors over a 23 km route.

Productivity measured in t/h applies where a certain amount of cane has to be moved within a given period. The tendency was for productivity to increase as load increased (Figure 5). The more powerful tractors, or those with higher gear ratios, were more productive than the others at all payloads.

Speed was significant when cycle time was considered, but declined when load was increased (Figure 6). Tractors with greater drawbar pull (such as the Ford TW's) had an advantage in that their speed did not decline as rapidly as with the smaller tractors when loads were increased.

Fuel consumption expressed in ℓ/t.km is a more useful expression than ℓ/h or ℓ/100 km in the context of haulage, because it indicates the efficiency with which a particular tractor can use fuel to pull a specific load over a given distance. There was a rapid decrease in ℓ/t.km as the load increased which indicates that fuel consumption was more efficient at higher loads for all tractors (Figure 7). The fuel consumption of the

Ford 5610 and MF275 formed the upper and lower limits respectively for the smaller tractors which were tested.

If haulage capacity and fuel consumption were equally important when choosing a tractor (ignoring cost, proximity of the dealer, etc), they could be combined to form a performance factor by dividing the number of ton.km by the product of fuel (ℓ) and time (h) (Table 2). The performance index of each tractor has been expressed as a percentage of the highest value of the performance factor (Figure 8). If fuel consumption is weighted in the index according to the fuel cost per hour, expressed as a proportion of the total tractor cost per hour, the relative position of the tractors does not change.

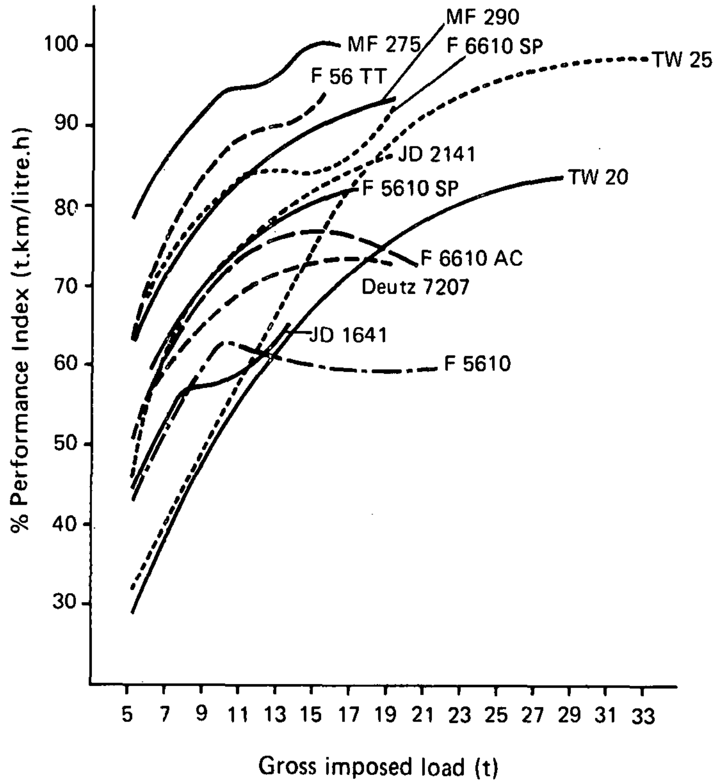

FIGURE 8 Performance index vs gross imposed load for all tractors with equally weighted haulage capacity and fuel consumption over a 23 km test route.

Discussion

In testing a large range of tractors, it was found that heat generated by the engine and exhaust caused driver fatigue which was aggravated by wind and sun.

Some gearboxes are of the continental column-shift type for both high and low ratio levers, but the driver preferred a floor-shift type. For haulage, several gear changes are necessary within a short period of time and this makes the synchromesh gearbox more suitable than the older type constant mesh gearbox.

The underdrive or dual-power facility for intermediate gear ratios is an advantage but the electrically operated version should be switched from the gear lever rather than the dashboard panel. The disadvantage of the mechanical version which is usually mounted on the floor is that the underdrive and gear levers occasionally have to be engaged simultaneously.

Modern tractors are capable of higher speeds and carrying heavier loads so the addition of 'fail-safe' air brakes should be carefully considered as well as mass transfer hitches, tyre and lug configurations, and reinforced rims.

Conclusion

High speed haulage tractors, fitted with ADE engines, have recently been developed. These haulage units should be compared carefully in terms of power output, productivity, speed and fuel consumption before selecting a new tractor. The limitations imposed by the Natal Road Traffic Ordinance become a serious consideration because they can be exceeded by the higher speeds of some tractors. However, the work being done by the manufacturers in improving their product augurs well for the future of transporting sugarcane over short distances.

REFERENCES

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2. S Afr Sug Ass Exp Stn (1984). *Mechanization report 84/1:* 1-14.