CORRELATION BETWEEN SCALE MODEL WIND TUNNEL TESTS AND FULL SCALE FUEL CONSUMPTION

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Abstract This paper reports the methods used, and results obtained, in two separate investigations carried out in the RMIT Industrial Wind Tunnel and duplicated on the road.

The results show that model-scale tests in a wind tunnel can be used as predictors for the likely fuel consumption changes effected by external geometry modifications to road vehicles.

Since on-road tests are time-consuming and costly, only devices that show promise in the wind tunnel need be studied in full scale, provided certain restrictions are realised.

Introduction During 1984 two separate investigations were carried out by staff and students of RMIT. The first was a study of the effects of geometry changes to passenger car drag, Gregory (1), the results of which were compared with actual fuel consumption changes measured on the road, Hird and Gregory (2). The car was a highway chase car used by the Victoria Police.

The second investigation centred on the possible fuel savings obtained by aerodynamic modifications to tri-axle tipper trucks. The work was commissioned by the New South Wales Energy Authority, Watkins et al (3). Both model tests were carried out in the 3 m x 2 m Industrial Wind Tunnel at RMIT, Hird (4).

Victoria Police Car Tests In answer to a request from the Victoria Police, model tests were performed on a 1/4 scale sedan car model to ascertain the drag increases (and other aerodynamic property changes) likely to occur by the addition of roof-mounted warning gear (lights and horns). Three configurations were tested as used by the police. While the model was available, further tests were performed namely ; attaching a streamline fairing to the span-light police configuration, attaching taxi hiring and advertising signs as commonly seen on city and suburban taxis in Melbourne, and attaching bull bars.

CONFIGURATION	$\Delta(C_D.A)$%	Δ(FC)%	DECREASE IN TOP SPEED (km/h)
Baseline	0	0	0
Spanlight	58.2	13.9	9.4
Spanlight + Fairing	21.5	5.6	3.4
Horns 1	17.3	4.6	3.2
Horns 2	30.8	8.6	5.5
Taxi Dome	14.1	-	-
Taxi Advert	10.1	-	-
Taxi Dome + Advert	14.1	-	-
Bull Bar	3.8	-	-

TABLE 1 INCREMENTAL DRAG AND FUEL - CAR TESTS

The increases in zero-yaw drag force obtained over the baseline model are given in Table 1 as a listing of $\Delta(C_d.A)$ % All tunnel tests were carried out at a Reynolds number of 1.2×10^6 per metre, and a longitudinal rms turbulence level of 1.5 % The fuel consumption figures are also given as a percentage over baseline.

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Upon request, the Victoria Police made available a road car and roof-mounted gear. The vehicle was fitted with a digital fuel meter and, for each configuration, two return runs of 117.5 km were made along a section of the Hume Highway. All runs were planned at 97.5 km/h, the average of all runs being 97.54 km/h with a standard deviation of 0.5 km/h. The total fuel usage was recorded. The vehicle mass was identical at the start of each run. The road was dry throughout the duration of the tests and days were selected for testing such that there was negligible wind. Thus the only flow difference between each run was that of other vehicle wakes.

A mock-up foam fairing was used on the span light to model the previous wind-tunnel tests.

A further test was carried out at a proving ground to determine the degradation in top speed due to the roof-mounted devices.

Interpretation of Sedan Car Tests Figure 1 shows a plot of incremental fuel consumption against incremental model drag, all essentially at zero yaw angle. Since no similar data could be found in the literature, data from Rose (5) on truck drag reductions are also presented. Further, a prediction of likely fuel savings from reduction of fuel consumption with reducing drag coefficients on European sedan cars, Hucho (6) has been re-interpreted to compare with this study and is also incorporated in Figure 1.

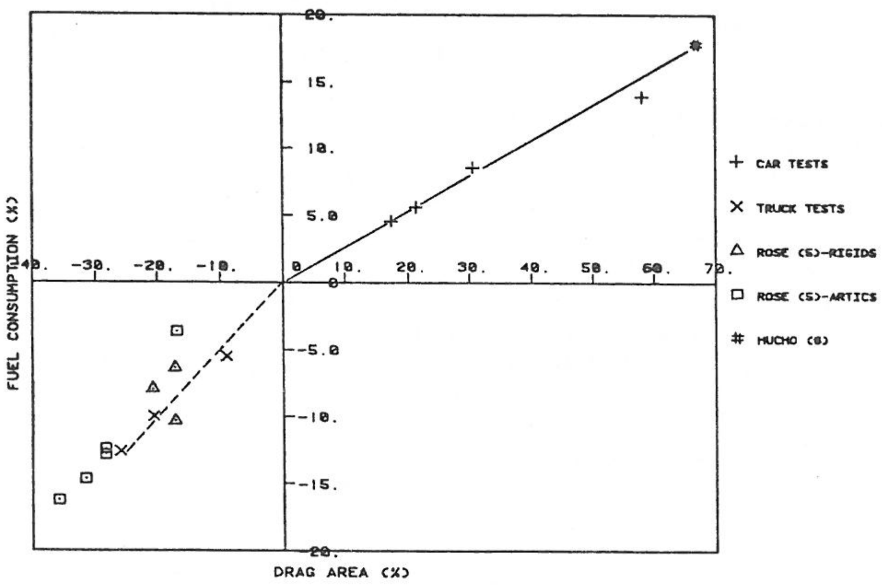

FIGURE 1 CORRELATION BETWEEN ON-ROAD FUEL CONSUMPTION AND WIND-TUNNEL DRAG

It can be seen that a strong correlation exists between full-scale fuel use and model-scale drag. It is sufficiently strong to be able to advise taxi fleet operators that the use of the dome sign and advertising hoarding could result in nearly 6% increase in fuel usage on suburban freeways at speeds approaching 100 km/h.

New South Wales Energy Authority Tests Following discussions between the New South Wales Energy Authority, Aztec Transport Services and RMIT, a study was undertaken on aerodynamic drag-reducing devices for articulated tipper trucks. The initial phase of the work was a series of tunnel tests on a 1/10 scale MACK R686 bonneted prime mover, coupled to an ALCAN tri-axle tipper trailer. Aerodynamic add-on devices were tried individually, and in various combinations and are described in Table 2.
If the wind-tunnel results were sufficiently encouraging, it

was proposed that the most promising practical combinations were then manufactured in full scale for road testing.

Unlike many production cars, the majority of articulated trucks exhibit large increases in aerodynamic drag with quite small increases in yaw angle. In addition to generating a non-zero yaw angle, ambient winds change the relative airspeed experienced by the moving vehicle. A process of wind-averaging the wind-tunnel drag coefficient has been developed by Buckley et al (7) to cope with the primary effects of winds. The procedure simulates the long-term steady wind environment and provides a single drag coefficient which is more representative than any drag coefficient obtained at a single yaw angle. It is a particularly useful technique for ranking drag-reducing devices whose performance is a function of yaw angle. This procedure has been applied (for average Australian conditions) to the results presented in Figure 1 and Table 2, denoted by $\bar{C}_D$.

CONFIGURATION	$\Delta(\bar{C}_D.A)$%	Δ(FC)%
Baseline	0	0
Tarpaulin	-20.5	-10.0
Tarpaulin + Fairing	-25.5	-12.6
Tarpaulin + Fairing + Skirts	-31.5	-
Fairing + Gate Fairing	-9.0	-5.5

TABLE 2 INCREMENTAL DRAG AND FUEL TIPPER TRUCK TESTS

Previous work at RMIT (8) indicated that the results for the best of the devices tested in the tunnel should translate to about 10 % fuel savings on the road, under realistic road conditions. It was thus decided to proceed with the second stage of the work; to manufacture full-size devices and verify their performance by on-road testing.

The harsh work environment of tipper trucks precluded the use of the trailer skirts on the road.

<u>Tipper Trucks - Road Tests</u> Two unladen, geometrically-similar, vehicles were supplied by Aztec Transport Services and were instrumented with in-line fuel monitoring systems and stop-watches. To monitor the wind conditions an instrumented car was used.

The test route ran south from Sydney on the Hume Highway, from the 50 km to the 90 km marker. All tests were run at 100 km/h, and road conditions were dry with only light traffic. The two trucks completed several runs with no aerodynamic devices fitted during testing, to establish a calibration factor.

A total of 600 km were accumulated during the calibration runs, and an average of 500 km were travelled for each test with devices fitted. Providentially, each test encountered a range of yaw angles from zero to nine degrees and the average windspeed was very close to that used in the tunnel wind-averaged drag calculations. The ambient windspeed measured at a height of 3 m averaged 11.5 km/h for the tests with devices. The percentage fuel savings for the devices tried are shown in Table 2 and the results of the tunnel and road studies can be seen plotted with the car data on Figure 1.

<u>Interpretation of Truck Data</u> The data from Rose (5) was obtained at zero yaw angle in the tunnel, and in on-road situations where the wind was 16 km/h or less. For the road conditions, yaw angles of up to 11.5 degrees could be generated but this was not reproduced in the tunnel. This is thought to be the major

cause of scatter. The present study wind-averaged the data from the tunnel, and the road tests covered a range of yaw angles and relative windspeeds. It was found that this contributed to improving the correlation between road and model scale, Watkins et al (3), although some scatter was still evident, which was thought to be due to an inability to reach full-scale Reynolds number and a lack of turbulence simulation in the tunnel tests.

Overall Conclusions As a strong correlation exists between tunnel and road tests for vehicles of the same type and weight, when travelling at the same speed, it is concluded that;

1) close predictions can be made for fuel changes resulting from the external geometry changes ;
2) the tunnel is a good tool for design and diagnosis and can determine if devices are worthy of full-scale evaluation.

It is further concluded that a relatively cheap wind-tunnel investigation can have substantial beneficial effects on the time and cost of full-scale vehicle aerodynamic studies. However, if the vehicles or devices are sensitive to yaw angle, or to other effects of ambient winds, it is recommended that the procedure of wind-averaged drag be considered.

References

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