INFLUENCE OF VEHICLE SELECTION ON OFF-TRACKING

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1. INTRODUCTION

This paper discusses the influence of vehicle selection on the off-tracking characteristics of vehicles. In particular it considers the differences that exist between configurations (rigid truck, semi-trailer, truck-trailer etc) and the effect on off-tracking by interchanging trailers.

Discussion on the implications of every combination or dimensional variation is a task significantly larger than that considered appropriate for this forum. Accordingly, a case study approach has been taken which focuses on the more popular combinations. Within each of these groups several variations have been considered to demonstrate the effect on off-tracking.

It should be noted that this paper is confined to the slow-speed off-tracking of vehicles. As such what may have a beneficial effect on the slow-speed characteristics of a combination could have an adverse effect on the vehicle's tailswing, high-speed off-tracking, stability or weight carrying capability.

2. BACKGROUND

When a vehicle executes a turn the path followed by the rear wheels is not the same as the path followed by the steering wheels. Instead, the rear wheels cut the corner which results in the radius of the rear part of the vehicle being less than that at the front. This phenomena is known as off-tracking and can, depending on the size of the vehicle, and the presence of any trailers, have a significant effect on its "manoeuvrability".

Often the effect of off-tracking is most noticeable in constrained areas such as at intersections, entering a driveway or manoeuvring around obstacles in a yard. In most situations the off-tracking behaviour has been taken into consideration when the intersection or site was designed, but when it has not, or the type of vehicle present is significantly different to that expected, the implications can be potentially serious.

3. IMPLICATIONS OF VEHICLE CHARACTERISTICS

3.1 Differences between vehicle types

The regulations that are imposed on New Zealand vehicles limit not only the overall length of the vehicle but also some of the "internal" dimensional characteristics.

As a result operators tend to tailor the use of the vehicles to the type of job by having small trucks servicing the needs of the small and light deliveries and larger combinations being used for bulky or heavy consignments. When this is not possible large combinations are used in place of the smaller ones. The overall effect of this is that although the load carrying capability of the replacement vehicle exceeds that required, its off-tracking characteristics may be significantly different.

To demonstrate the marked differences in the swept paths of different vehicle configurations, representative vehicles have been selected and their steady state off-tracking characteristics assessed. *Figure 1* illustrates these differences and has been presented in a manner which shows the width of the swept path needed to successfully complete the turns at different radii.

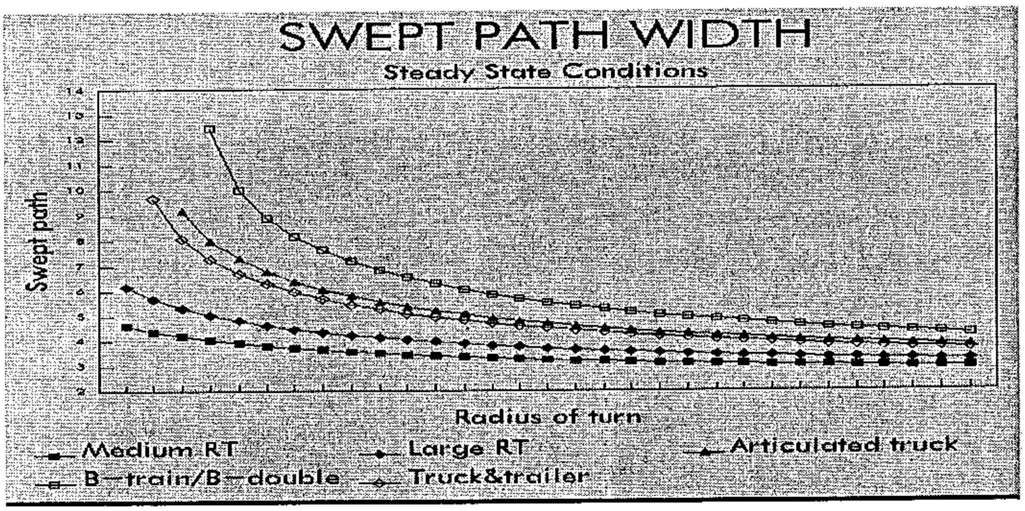


Figure 1

Clearly as the radius of the turn decreases the width of the swept path increases. With small changes in very large radii the differences in the width of the swept path are small. However, as the radius is decreased from what could be regarded as a relatively tight turn the effect on the off-tracking becomes very significant.

Each curve is parabolic in nature and has an asymptote which represents the radius below which the trailer will reverse if the steady state turn is attempted.

With respect to the different vehicle configurations, the vehicle that displays the least off-tracking is the rigid truck. The combination that has the greatest off-tracking is the B-train.

If the dimensional characteristics of some of these larger vehicles were to be modified it is possible for the B-train (for example) to have less off-tracking than a truck and trailer or a semi-trailer. Equally if the dimensions of the truck and trailer or semi-trailer were to be increased their swept path characteristics could exceed that of the B-train. It is this very fact that was responsible for some of the restrictions in the recently implemented 20 metre/44 tonne truck-trailer policy.

3.2 Simplistic method of assessment

The most simplistic form of assessing the off-tracking characteristics of a vehicle or combination is to consider the vehicle turning in a steady-state manner. In this situation the driver has turned the steering wheel to a certain "lock" and has held the wheel in this position while travelling around and around in a circle. After several complete circles the off-tracking of the rear-most unit in the combination will have stabilised (assuming the turn was not too tight).

A simple mathematical equation can be applied to assess this stabilised performance. The answer is in effect the radius of the off-tracking, and if other factors are ignored can be used as an "off-tracking index" to compare the performance of other combinations under the same conditions.

The equation is as follows:

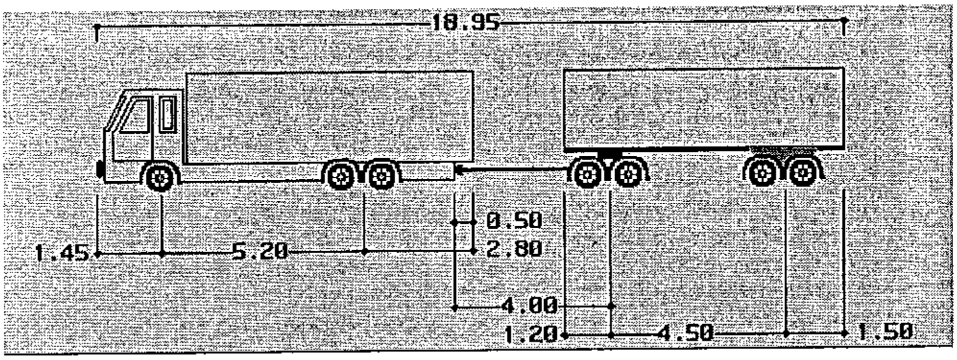
$$OT = (R^2 - \Sigma(W_i^2) + \Sigma(S_{i-1}^2))^{1/2}$$

where OT is the off-tracking "index"
R is a selected "radius"
W_i is the "wheelbase" of each unit
S_i is the separation between the rear axis of one unit and the point of attachment on that unit of the following unit

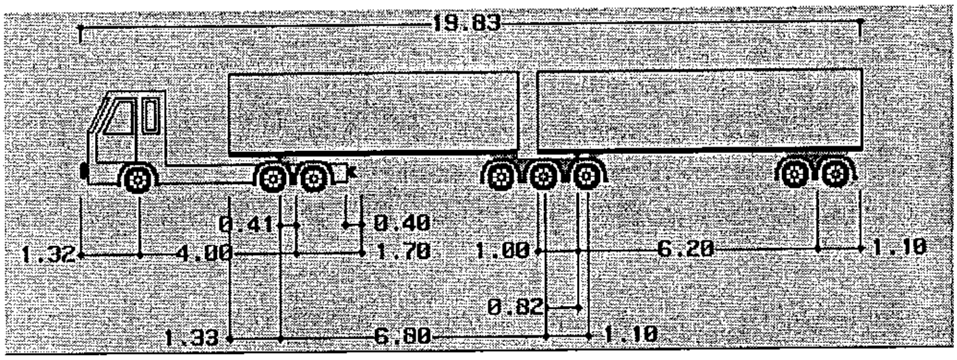
It should be noted that if R is made too small (for example 10m) a sensible answer for OT may not be possible. It is therefore recommended that R be in the order of 15 to 20 metres. The turning radius that is selected is <u>not</u> the same as that defined in the Regulations or vehicle specification sheets (equations are available to make these corrections).

The dimension "W" is the forward distance of simple and semi-trailers. In addition to the wheelbase of a full trailer it is also important to include the distance between the towing eye and the centre of the turntable.

To illustrate the use of the equation consider the following truck and trailer and B-train combinations.



Truck & trailer



B-train

Application of the equation to both of these vehicles results in the off-tracking "index" for a radius of 15m being:

Truck & trailer: OT $= (15^2-(5.2^2+4^2+4.5^2)+((2.8-0.5)^2))^{½}$
$= 12.92$

B-train: OT $= (15^2-(4^2+6.8^2+6.2^2)+(0.41^2+1^2))^{½}$
$= 11.20$

With the "index" of the B-train being less than that of the truck and trailer combination, the B-train can be expected to have worse slow speed off-tracking. If a third vehicle was to be assessed, or the dimensions of one of these two vehicles were changed, direct comparisons of the answers (for the same radii) can be made.

It should be noted that this method is only useful as a first order estimate and does not consider the real-world transient manoeuvring where the vehicle is pulling out of a turn shortly after entering it. In these cases, generalised mathematical equations are significantly more complicated.

To overcome these difficulties computer programs are available which simulate the manoeuvring of a vehicle in both forward and reverse directions. These often provide graphical output which shows the extent of the differences between vehicles throughout the turn or at constrained locations along a route.

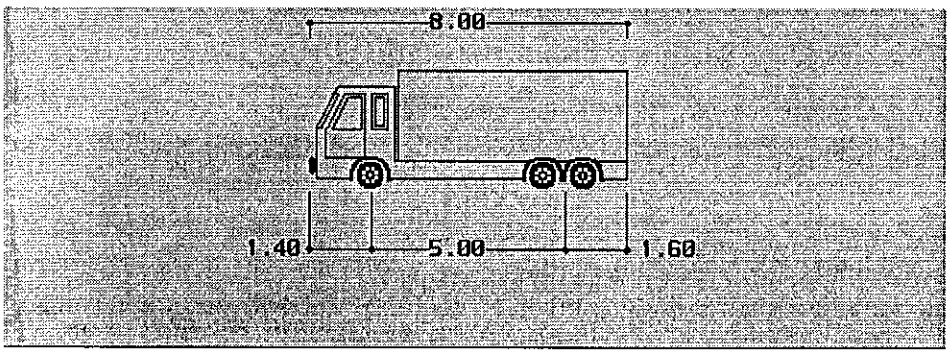
3.3 Interchanging of trucks and trailers

Transport operators frequently tailor the matching of trucks and trailers in their fleet to the specific needs of a job. This flexibility results in the greatest benefits and utilisation being obtained from the fleet but does have implications on the off-tracking characteristics of the combinations.

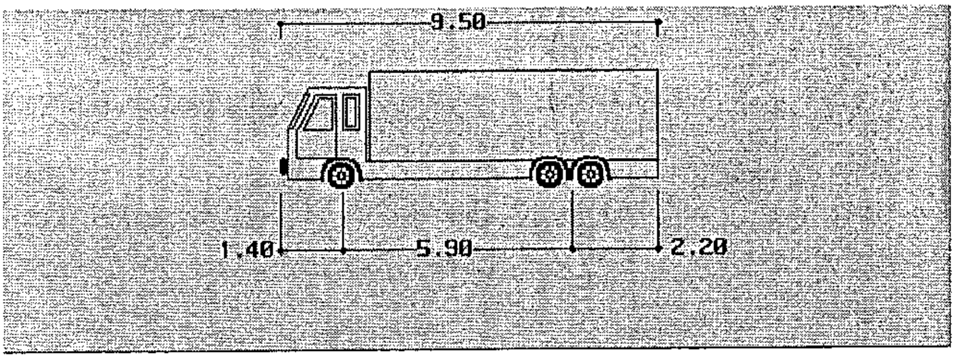
To illustrate the extent of these differences, a case study approach has been taken which will demonstrate the significance of some of the changes in a "real-world" situation. The impact of these changes have been assessed using two different manoeuvres, viz a relatively tight U-turn and a 90 degree turn to the right.

3.3.1 Rigid Truck

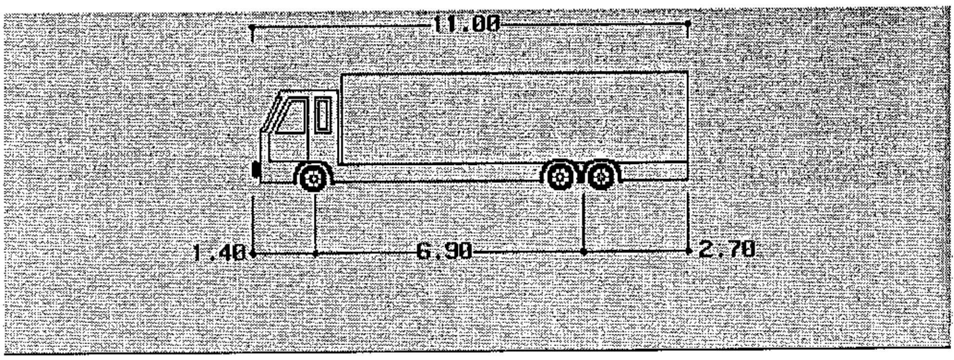
Consider the following three vehicles.



RT1



RT2



RT3

Under the current regulations the gross weight of vehicles RT1, RT2 and RT3 is 21, 21.5 and 21.5 tonnes respectively.

The off-tracking characteristics of these three vehicles executing a relatively tight 90 degree and 180 degree turn is shown in *Figure 2* at the end of this paper.

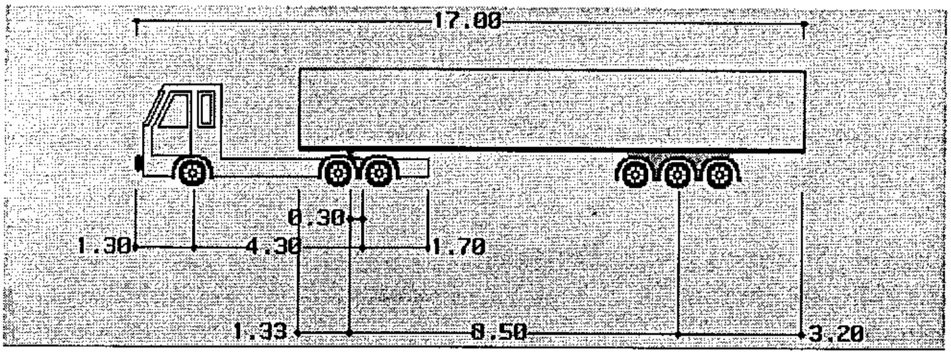
Considering the 90 degree turn first, the vehicle that displays the least off-tracking is the 8 metre long vehicle. The vehicle that has the most off-tracking is the 11 metre vehicle, with its off-tracking being approximately 0.9 metres more that the 8 metre vehicle.

As the angle through which the vehicle turns increases, the off-tracking of the vehicles also increase. In the case of the 180 degree turn shown, the maximum difference between the 8 metre and 11 metre long vehicle is now 1.2 metres. The difference between the off-tracking of the 9.5 metre and 11 metre vehicles is approximately 0.7 metres

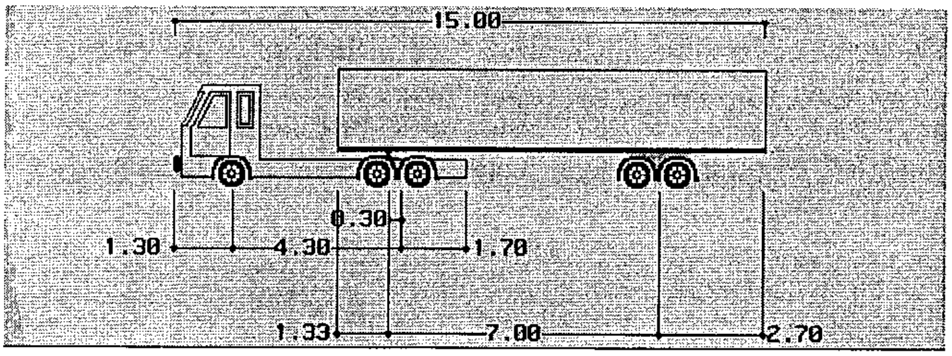
Clearly if a manoeuvring area or access road has been designed to accommodate the smaller vehicles the ease of movement and resulting clearances will be adversely affected by the use of a larger vehicle.

3.3.2 Semi-trailer/Articulated truck

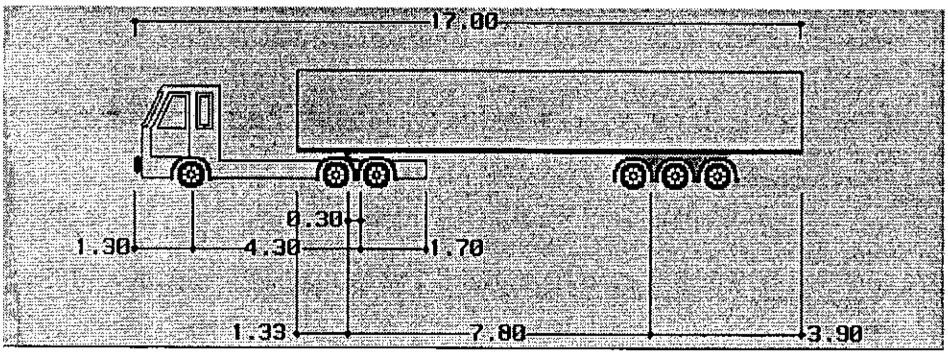
Consider the following three vehicles.



ST1: 17m ST (max legal)



ST2: 15m ST



ST3: 17m ST (with castoring axle)

It should be noted that the tractor unit of each vehicle is the same. This eliminates secondary influences created by the dimensional variations of the tractor and results in the off-tracking differences between the vehicles being solely attributable to the characteristics of the trailer.

Under the current weight regulations the gross vehicle weight of vehicles ST1, ST2 and ST3 is 39, 37 and 36 tonnes respectively.

If these three vehicles executed the same relatively tight 90 degree and 180 degree turn followed by the rigid trucks, their off-tracking characteristics would be as shown in *Figure 3* at the end of this paper.

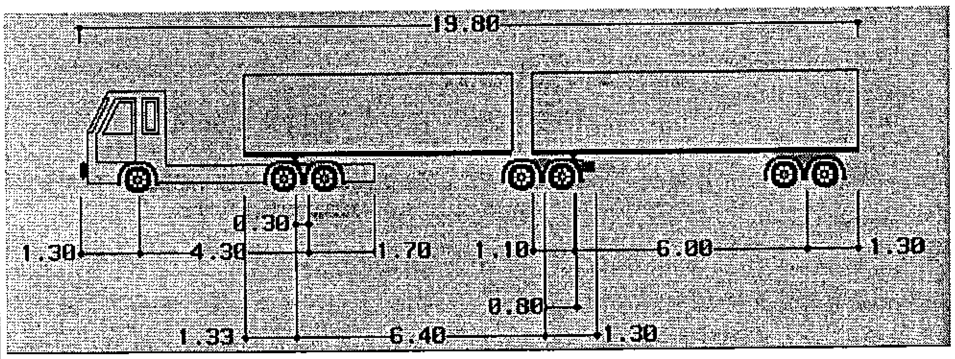
Considering the behaviour of the vehicles executing a 90 degree turn first, the vehicle that displays the least off-tracking is the 15 metre semi-trailer (ST2). The vehicle that has the most off-tracking is the full size semi-trailer (ST1), with its off-tracking being approximately 0.75 metres more than ST2.

With respect to the 180 degree turn, the maximum difference between the two fixed axle trailers is 1.3 metres, a difference which could be regarded as being particularly significant in constrained manoeuvring areas.

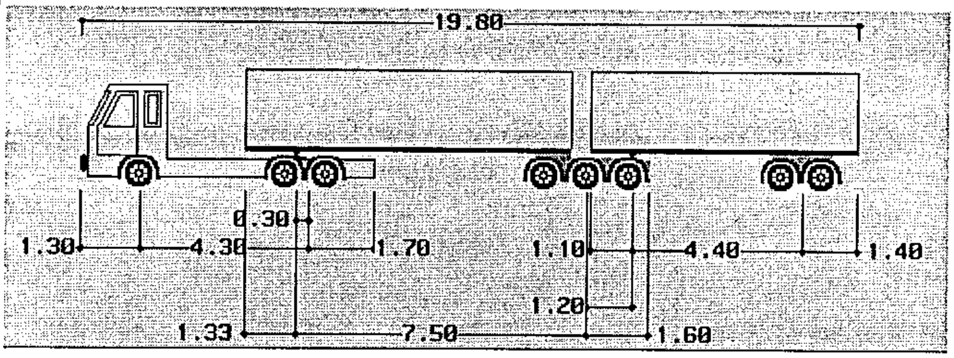
If the weight of the combination is less than the 37 tonne limit under the castoring axle policy (39 tonnes is currently being considered) there are slow speed off-tracking advantages in using the castoring axle trailer. For example the off-tracking difference between it and the full size trailer through a 180 degree turn is approximately 0.6 metres.

3.3.3 B-train/B-double

Consider the following two combinations with the same tractor unit:

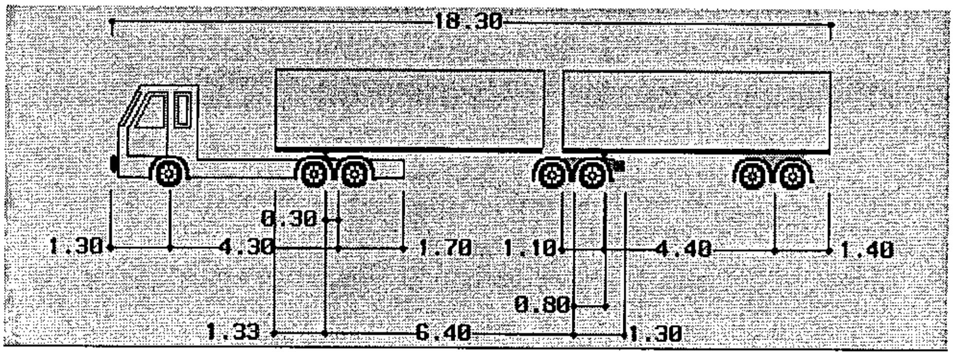


BT1: 20m B-train (max legal)

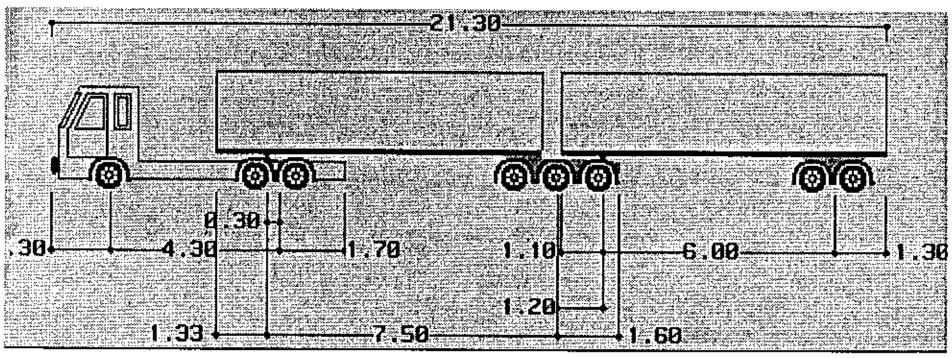


BT2: 20m B-train (max legal)

It is also possible to interchange these trailers to get two more combinations:



BT3: First trailer from BT1, second trailer from BT2



BT4: First trailer from BT2, second trailer from BT1 (ILLEGAL)

It should be noted that this interchanging has resulted in the overall length of vehicle BT4 exceeding the legal maximum overall length (20 metres) and trailing length behind the fifth wheel of the tractor (14.5 metres).

Ignoring the overall length aspects of the vehicles, the current regulations allow the gross weight of each vehicle to be 44 tonnes.

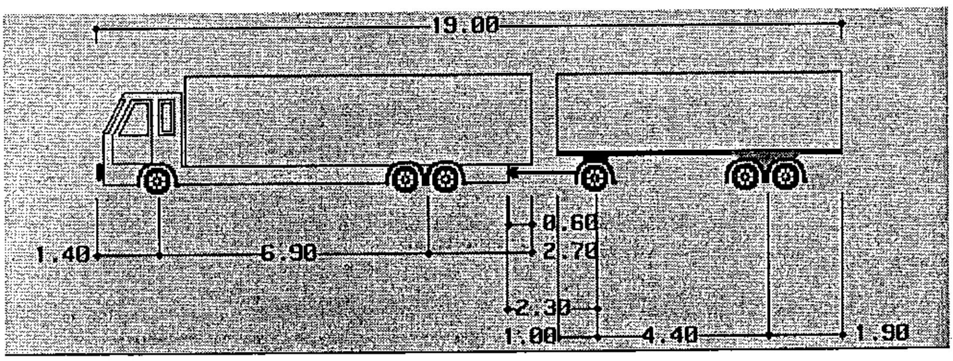
If these vehicles were to execute the same relatively tight 90 degree and 180 degree turn their off-tracking characteristics would be as shown in *Figure 4.*

Considering the 90 degree turn first, the vehicle that displays the least off-tracking is the combination that uses the smaller of the trailers. The vehicle that has the most off-tracking is the combination that uses the larger trailers, with its off-tracking being approximately 0.9 metres more. With respect to the 180 degree turn, the maximum difference between these two vehicles increases to 1.8 metres. Therefore the implications on off-tracking and dimensional integrity can be significant if trailers are interchanged.

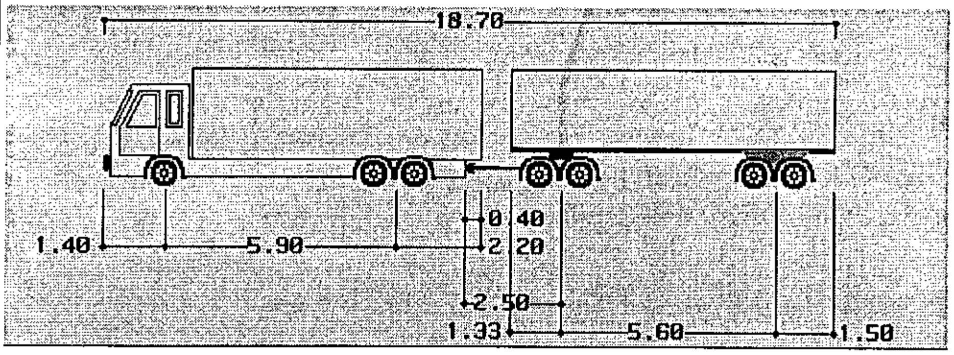
With respect to the two "standard" vehicles (BT1 and BT2), their dimensional differences are such that there is little between their off-tracking behaviour. Should comparisons be necessary vehicle BT1 is slightly worse than BT2 by approximately 0.1 metre through the 90 degree turn and 0.15 metre through the 180 degree turn. These differences are unlikely to be noticeable to most drivers.

3.3.4 Truck & trailers

Consider the following two truck and trailer combinations, each of which can legally carry 42 tonnes.

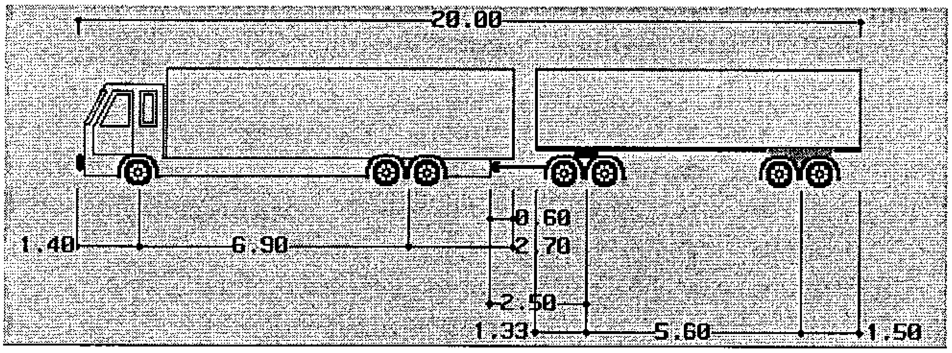


TT1

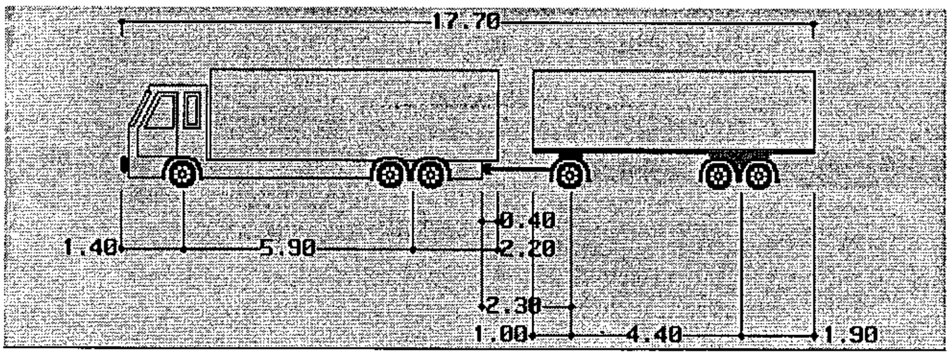


TT2

By interchanging these trucks and trailers two more combinations can be obtained:



TT3



TT4

The gross weight of vehicle TT3 is 44 tonnes and 41 tonnes for vehicle TT4. In addition to these limitations vehicle TT3 also has to comply with the requirements of the 20 metre/44 tonne policy.

If these vehicles were to execute the same relatively tight 90 degree and 180 degree turn their off-tracking characteristics would be as shown in *Figure 5.*

Of these four combinations, vehicle TT3 has the worst off-tracking with vehicle TT4 having the least off-tracking. The difference between the two is approximately 0.9 metres through a 90 degree turn and 1.4 metres through a 180 degree turn.

Vehicles TT1 and TT2 have near identical off-tracking characteristics with virtually indistinguishable differences through the 90 degree turn and up to 0.1 metre through the 180 degree turn.

Again, as with the B-train, the influence of vehicle selection and interchanging of trailers can have a significant effect on the off-tracking characteristics of vehicles.

3.3.5 Other factors

There are other factors that can influence the off-tracking of a vehicle beside the dimensional variations that have been briefly discussed above. These generally fall into two groups, one concerned primarily with factors associated with the vehicle itself and the other the factors associated with the surrounding environment.

With respect to the vehicle-related group, influencing factors can include the gross weight of the vehicle and the positioning of the load on the deck of the truck, the effectiveness of a load sharing suspension, the axle arrangement in an axle group, the presence of any tag or lifting axles and the condition of the tyres. These can significantly affect the position of the rear axis of the truck or a trailer which in turn directly influences the slow speed off-tracking characteristics of the vehicle. Research has shown that this effect is particularly noticeable on widely spaced heavily laden axle sets.

The factors associated with the surrounding environment include such things as the type (loose gravel, concrete, tar sealed) and condition (new, worn, oily) of the pavement surface which influences the coefficient of friction and the lateral gradient of any slopes the vehicle must travel over.

4. CONCLUSION

The selection of a vehicle for a particular use can have a significant effect on its slow speed off-tracking characteristics. This effect is particularly noticeable when consideration is not only given to the different configurations possible but also the combinations that are possible by interchanging trucks and trailers within a fleet or pool of vehicles.

An easily applied method can be used to quickly gauge the performance of one vehicle against another. Whilst only for first order estimates, it is considered useful to determine the off-tracking characteristics of a vehicle when other more accurate methods are not available.

For precise and realistic assessments computer programs are now available that can be used to demonstrate the influence on off-tracking of various combinations through any simple or complex manoeuvre.

These methods have been used to demonstrate that the influence of vehicle selection on off-tracking can be significant in some situations. Despite this it is possible to minimise any adverse impacts by matching the needs of delivery and constraints of the servicing areas to the capability of the vehicle.

Acknowledgments

The assessment of vehicle weights and graphical images of dimensioned vehicles have been obtained from the computer program "TruckMATCH" developed by Trident Software Ltd. Used with permission.

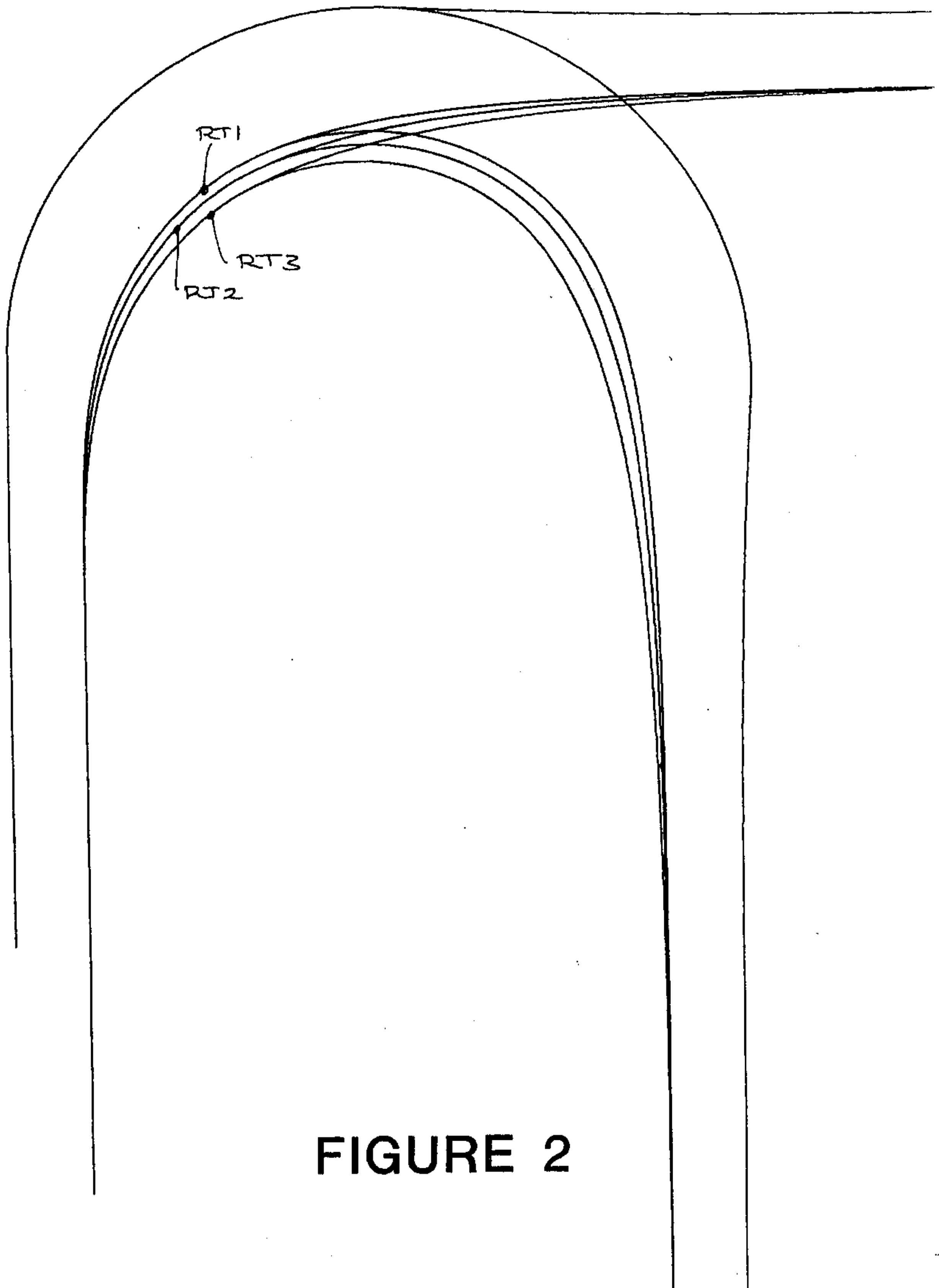


FIGURE 2

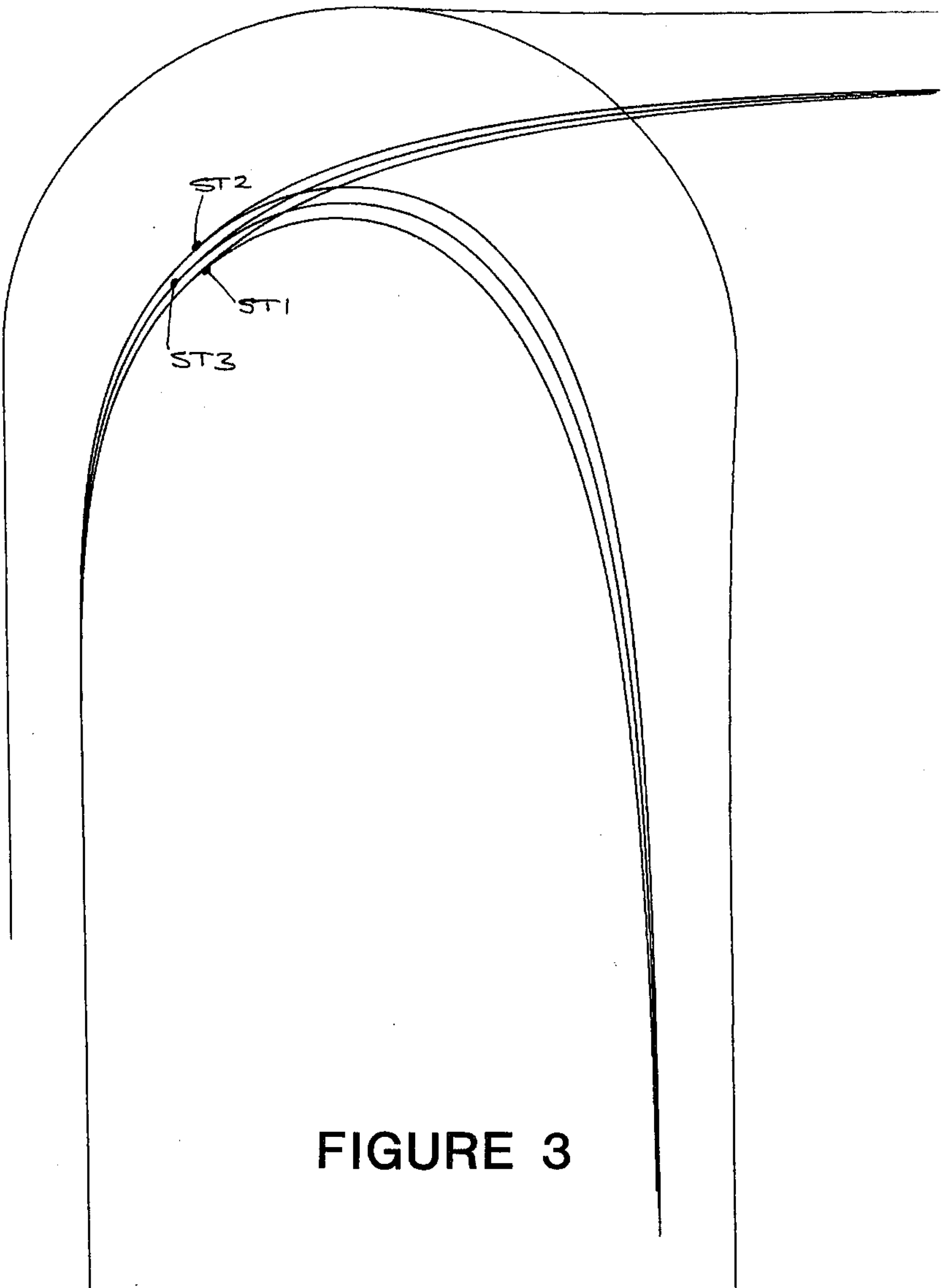


FIGURE 3

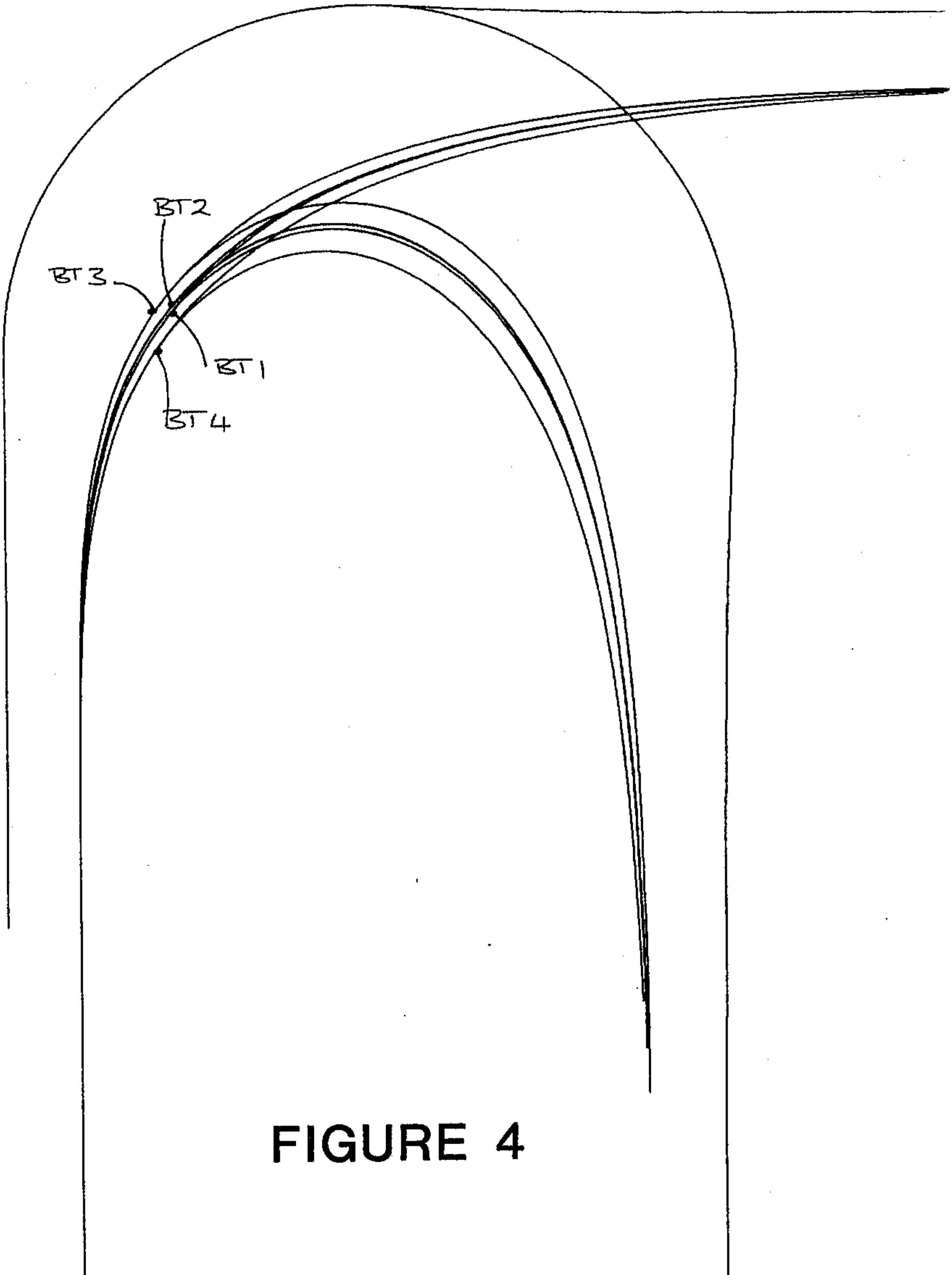


FIGURE 4

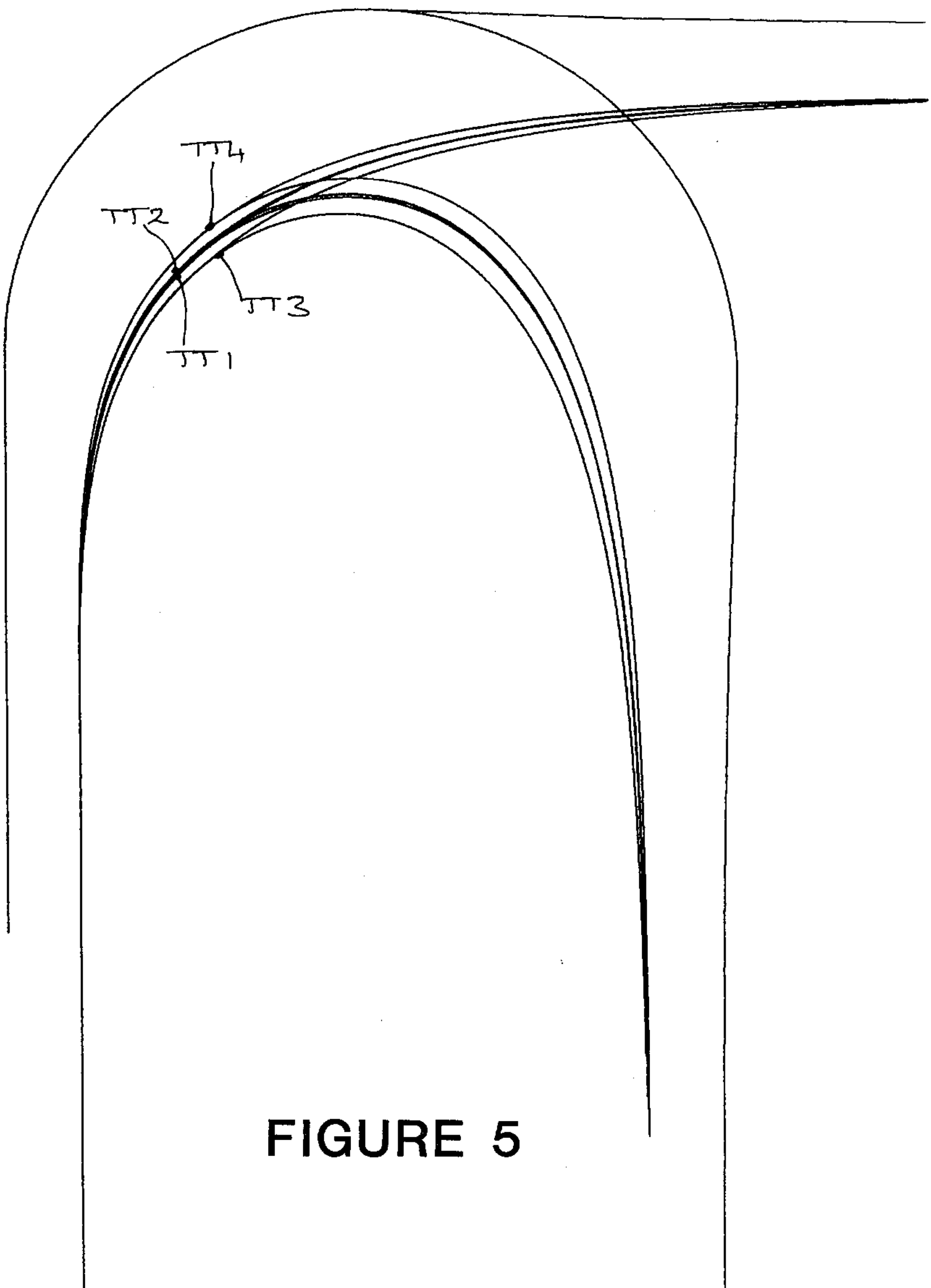


FIGURE 5