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THE RELATIVE JACKKNIFING TENDENCIES OF STINGER-STEERED AUTOMOBILE TRANSPORTERS

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16. Abstract

This report on the relative jackknifing tendencies of stinger-steered automobile transporters provides (a) a description of the methods used in the simulation study, (b) a presentation of the findings, and (c) a summary of conclusions. The basic finding of this study is that, for these types of vehicles, tractor wheelbase has a much greater influence on jackknifing tendencies than the location of the fifth wheel. That means that stinger-steered auto transporters have less of a jackknifing tendency than conventional tractor-semitrailers or auto transporters employing conventional fifth wheel locations, because the stinger-steered vehicles employ tractors with long wheelbases. Furthermore, 75-ft stinger-steered auto transporters are predicted to have less of a jackknifing tendency than the 65-ft auto transporters that are currently allowed (because the 75 footers would have longer tractor wheelbases than the current 65-foot units).

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Mr. Martin Hargrave
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Federal Highway Administration
Turner-Fairbank Highway Research Center
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REF: Contract No.
DTFH61-85-C-00091

Dear Mr. Hargrave:

The following material constitutes a letter report on the relative jackknifing tendences of stinger-steered auto transporters. This report has been prepared by UMTRI in accordance with the requirements of Task F of Federal Highway Administration Contract No. DTFH61-85-C-00091 entitled "Safety Implications of Various Truck Configurations."

The Federal Highway Administration has been considering regulations allowing the use of auto transporters with overall lengths up to 75 feet. In response to the docket on this change in regulation, the National Transportation Safety Board has expressed concerns with the jackknifing tendencies of stinger-steered auto transporters, because the "stinger" places the fifth wheel connection well behind the rear axle of the tractor. (In a conventional tractor-semitrailer, the fifth wheel is located over the rear suspension.)

In Task F of this project, UMTRI has performed a simulation study to address the jackknifing issue. The remainder of this report provides (a) a description of the methods used in the simulation study, (b) a presentation of the findings, and (c) a summary of conclusions. The basic finding of this study is that, for these types of vehicles, tractor wheelbase has a much greater influence on jackknifing tendencies than the location of the fifth wheel. That means that stinger-steered auto transporters have less of a jackknifing tendency than conventional tractor-semitrailers or auto transporters employing conventional fifth wheel locations, because the stinger-steered vehicles employ tractors with long wheelbases. Furthermore, 75-foot stinger-steered auto transporters are predicted to have less of a jackknifing tendency than the 65-foot auto transporters that are currently allowed (because the 75 footers would have longer tractor wheelbases than the current 65-foot units).

DESCRIPTIONS OF THE SITUATIONS USED IN COMPARING JACKKNIFING TENDENCIES

A comprehensive simulation [1,2] of the braking and steering of tractor-semitrailers was used to assess the relative jackknifing tendencies of the following vehicles:

1) a typical van-type tractor-semitrailer with a tractor wheelbase of 144 inches

2) same type of vehicle as (1) except with a tractor wheelbase of 216 inches

3) an auto transporter with a conventional fifth wheel location

4) a typical 65-foot auto transporter with a stinger fifth wheel

5) a postulated 75-foot auto transporter with a stinger fifth wheel

Existing data sets from previous studies were used to simulate conventional tractor-semitrailers with 144-inch and 216-inch tractor wheelbases. The National Automobile Transporters Association (NATA) was contacted for help in estimating the parameters describing auto transporters. This help included photographs of existing vehicles and arrangements for visits to inspect typical vehicles. Two features of importance are that (a) the foremost tractor rear axle is lifted when the auto transporter is empty and (b) an empty auto transporter is much heavier than an empty (typical) tractor-semitrailer because of the load racks and hydraulic equipment.

Discussions with NATA personnel and auto transporter manufacturers allowed us to estimate the design of a 75-foot auto transporter. Seventy-five-foot auto transporters do not exist now. If they were to be built, the trailer could be no longer than 48 feet (an influence of size and weight regulations). The stinger location might be increased from about 48 inches to 54 inches behind the rear axle but not any farther because the structure needed to support the fifth wheel would be too difficult and too massive to build practically. Hence, the remainder of the additional length would go into tractor wheelbase.

As long as the weight limit is 80,000 lbs, it is not clear whether additional cars could be carried, but users feel that longer transporters would be desirable to cut down on damage to the load. For this study, the empty vehicle is the prime consideration and the loading has not been increased to allow additional cars.

Since accident data [3] indicate that jackknifing is primarily an empty-vehicle problem, calculations were made with these vehicles in the unladen state. In addition, calculations were also made with the tractor of the transporter laden and the semitrailer unladen in order to determine whether this unique loading condition would yield worse results than those obtained for the empty vehicle. (It did not.)

The driver representation [1] in the simulation model was used to cause each of the vehicles to attain a steady turn with a lateral acceleration of 0.17 g at 55 mph. After the vehicle was in a steady turn, braking was applied so as to initiate jackknifing. Two types of braking were used in separate sets of calculations. The worst situation, leading to the most severe jackknifing tendency, occurs when the tractor rear wheels are locked up and the tractor front wheels are freely rolling. One of the sets of simulation runs was made in a condition referred to as "tractor front brakes and trailer brakes disconnected" in order to attain the most rapid jackknife possible.

This tractor-rear-brakes-only condition, although artificial, provides an excellent basis for making relative comparisons under comparable operating conditions. Furthermore, this type of approach has proven useful in previous studies [4].

The second set of braking conditions was with typical braking throughout the tractor-semitrailer combinations. In these cases, a brake pressure level was selected to lock the tractor rear brakes but not the tractor front brakes when operating on a slippery (poor texture) wet road. This more realistic braking scenario was used to examine the influence of brake proportioning on the jackknifing tendencies of the vehicles.

The results of the simulation are time histories of vehicle response variables. The particular variables of interest here are the yaw rate of the tractor and the articulation angle between the tractor and the semitrailer. The steering input is held fixed during the braking part of the braking-in-a-turn maneuver. Hence, the yaw rate and articulation angle responses are not "polluted" with attempts by the driver representation to correct the jackknifing response. (The jackknife reponses are so rapid and the driver representation is so slow that corrections would not be successful.)

A jackknife is characterized by a rapid increase in the magnitude of both the tractor yaw rate and the articulation angle (see Figures 1 and 2, for example). Two measures have been selected to evaluate the rapidity of a jackknife. These measures are the yaw rate doubling time and the articulation rate. The yaw rate doubling time is the time required for the yaw rate to increase from 1.05 times the steady-turn value to 2.0 times the steady-turn value (see Figure 1). The articulation rate reported herein is the average rate during the time the articulation angle increases from two to three times its steady-turn value (see Figure 2). The jackknifing tendency of a vehicle is judged to be greater than that of another vehicle if its yaw rate doubling time is smaller and its average articulation rate is greater than those of the other vehicle.

FINDINGS WITH REGARD TO JACKKNIFING TENDENCIES

The results of the simulation study when only the tractor wheels are braked are summarized in the bar charts presented in Figures 3 and 4. These charts show that the shortest yaw rate doubling times and the largest articulation rates occurred when the vehicles were completely empty and operating on a wet slippery surface. The results obtained when the tractors of the auto transporters were loaded are no more severe than those obtained with the empty vehicles.

Examination of the results presented in Figures 3 and 4 indicates that (a) the worst vehicle (the one with the greatest jackknifing tendency) is the conventional tractor-semitrailer having a tractor with a 144-inch wheelbase, (b) the auto transporter with the conventional fifth wheel location (and a typically short tractor wheelbase of 144 inches) is nearly as bad as the short wheelbase tractor-semitrailer, (c) the 65-foot auto transporter is slightly better than the conventional tractor-semitrailer with a 216-inch wheelbase, and (d) the 75-foot auto transporter has a slightly longer (better) yaw rate doubling time than the 65-foot auto transporter. The articulation rates of

the 216-inch-wheelbase conventional vehicle and the 65-foot and 75-foot auto transporters are practically equivalent on the slippery surface.

The difference between the jackknifing tendencies of the 65-foot stinger-steered auto transporter and the conventional tractor-semitrailer with a 216-inch wheelbase is very small, as can be seen by comparing Figures 5 and 6 with Figures 1 and 2, respectively.

The results are more dramatically in favor of the stinger-steered vehicles when normal braking is employed in the simulation. The reason for this is that the stinger-steered vehicles have a more favorable arrangement of vertical loads than the other vehicles when they are empty. This gives the stinger-steered vehicles an advantage which is clearly indicated in the bar charts shown in Figures 7 and 8.

SUMMARY OF CONCLUSIONS

With regard to jackknifing tendencies, the conclusions of this study are:

-Stinger-steered auto transporters are superior to many typical tractor-semitrailers. This is because they have longer tractor wheelbases when operated in the empty condition.

-The 75-foot auto transporter is predicted to be an improvement over the 65-foot auto transporter, which is much better than the auto transporter with a conventional fifth wheel location.

In addition to these conclusions, which are compatible with previous results on the influences of tractor wheelbase [4], other research has also shown that the stinger fifth wheel does contribute to an increase in rearward amplification of the tractor motion at the semitrailer, but that this increase is not large enough to create a rollover problem [3].

The results of this simulation study and other previous studies have not uncovered any special jackknifing or directional response problems pertaining to auto transporters.

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Very truly yours,

Paul S. Fancher

Paul S. Fancher
Principal Investigator

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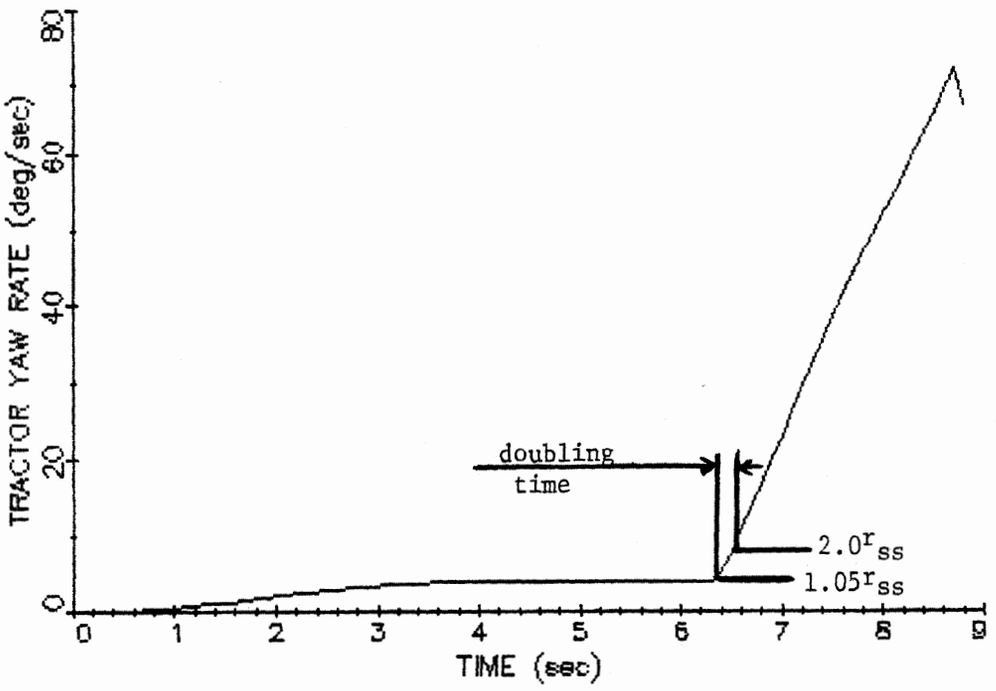
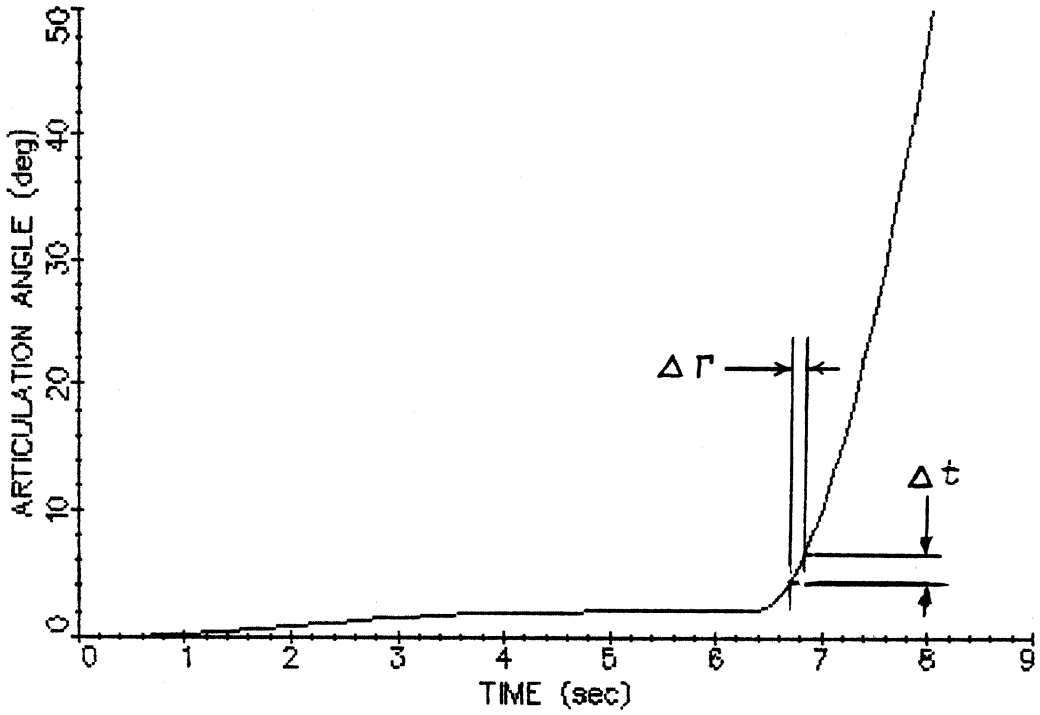


TRACTOR (216 IN) AND SEMITRAILER — EMPTY, WET SURFACE

Figure 1

Plotsee:



TRACTOR (216 IN) AND SEMITRAILER — EMPTY, WET SURFACE

Average articulation rate = $\Delta\Gamma/\Delta t$

Figure 2

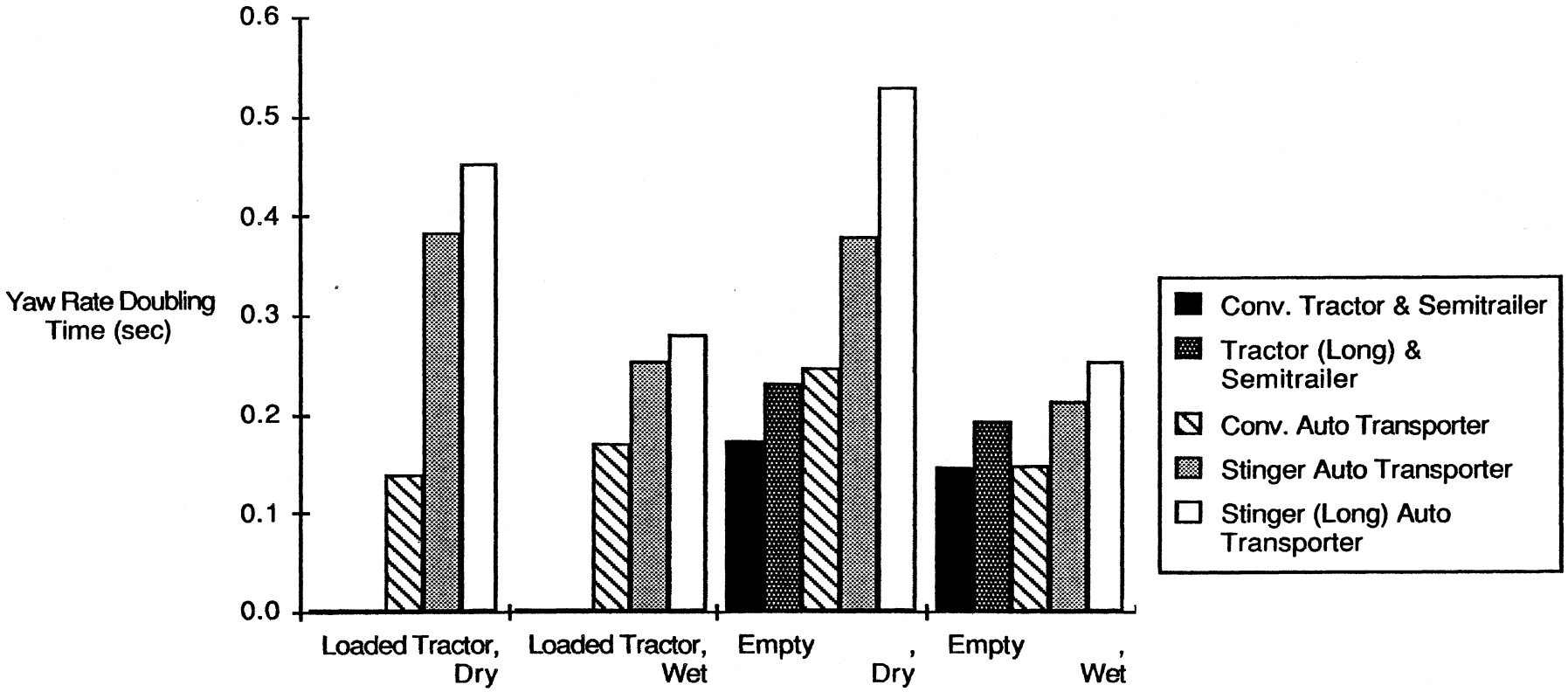


Figure 3

Tractor front brakes and trailer brakes disconnected

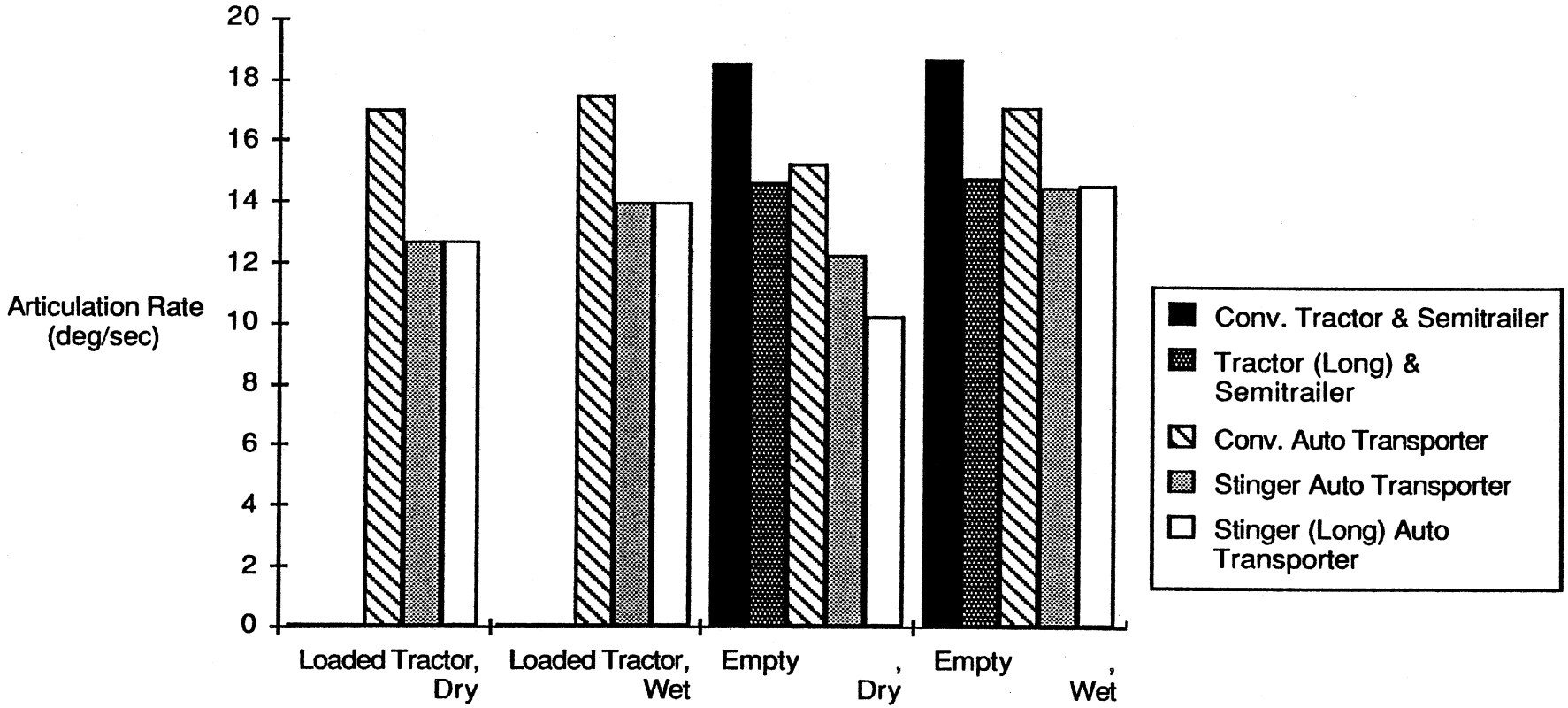


Figure 4

Tractor front brakes and trailer brakes disconnected

Plotsee:

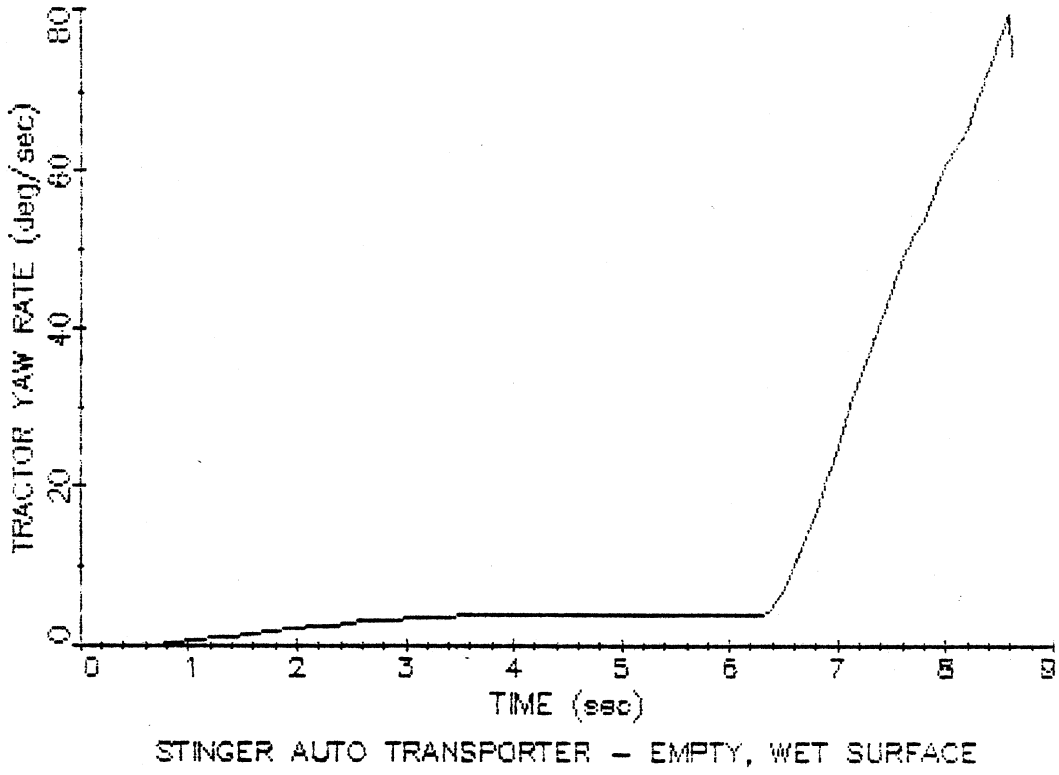


Figure 5

Plotsee:

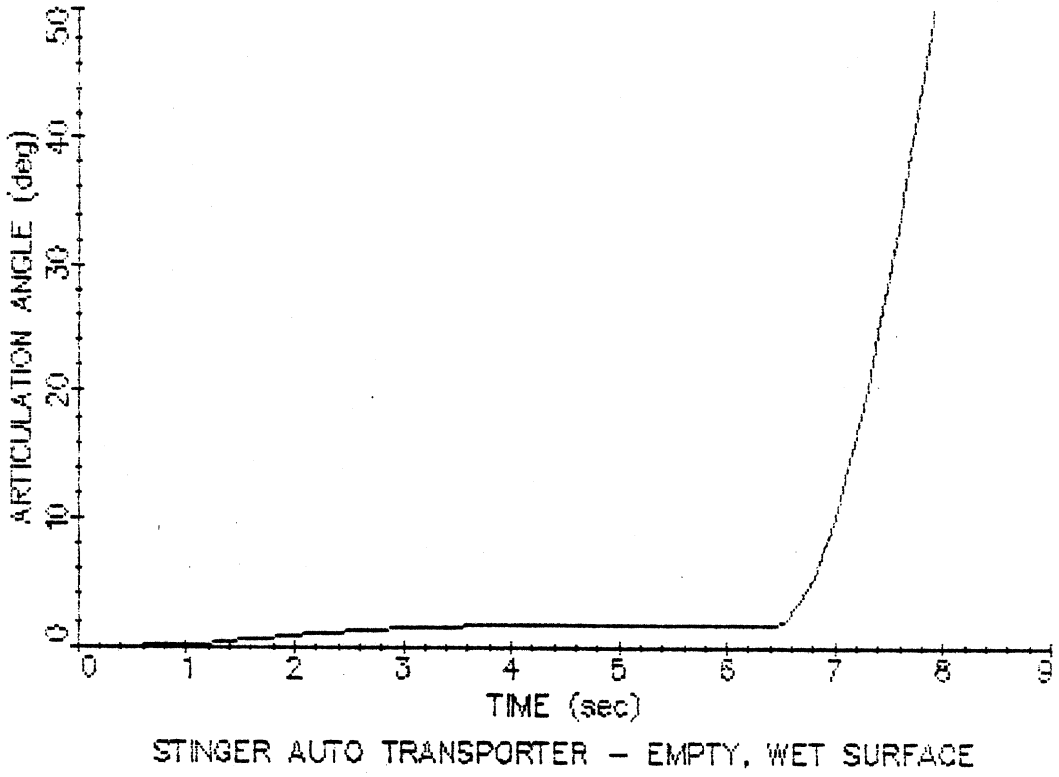


Figure 6

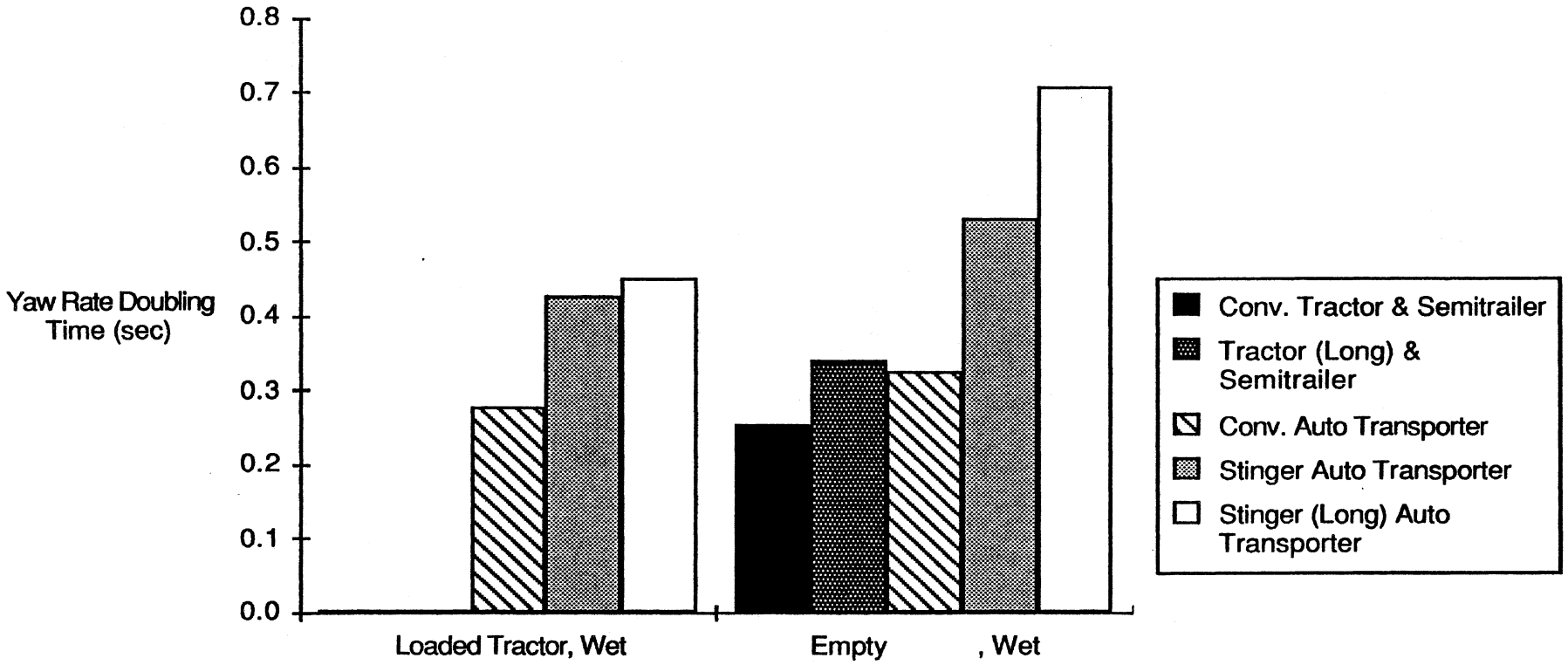


Figure 7

Braking on all wheels

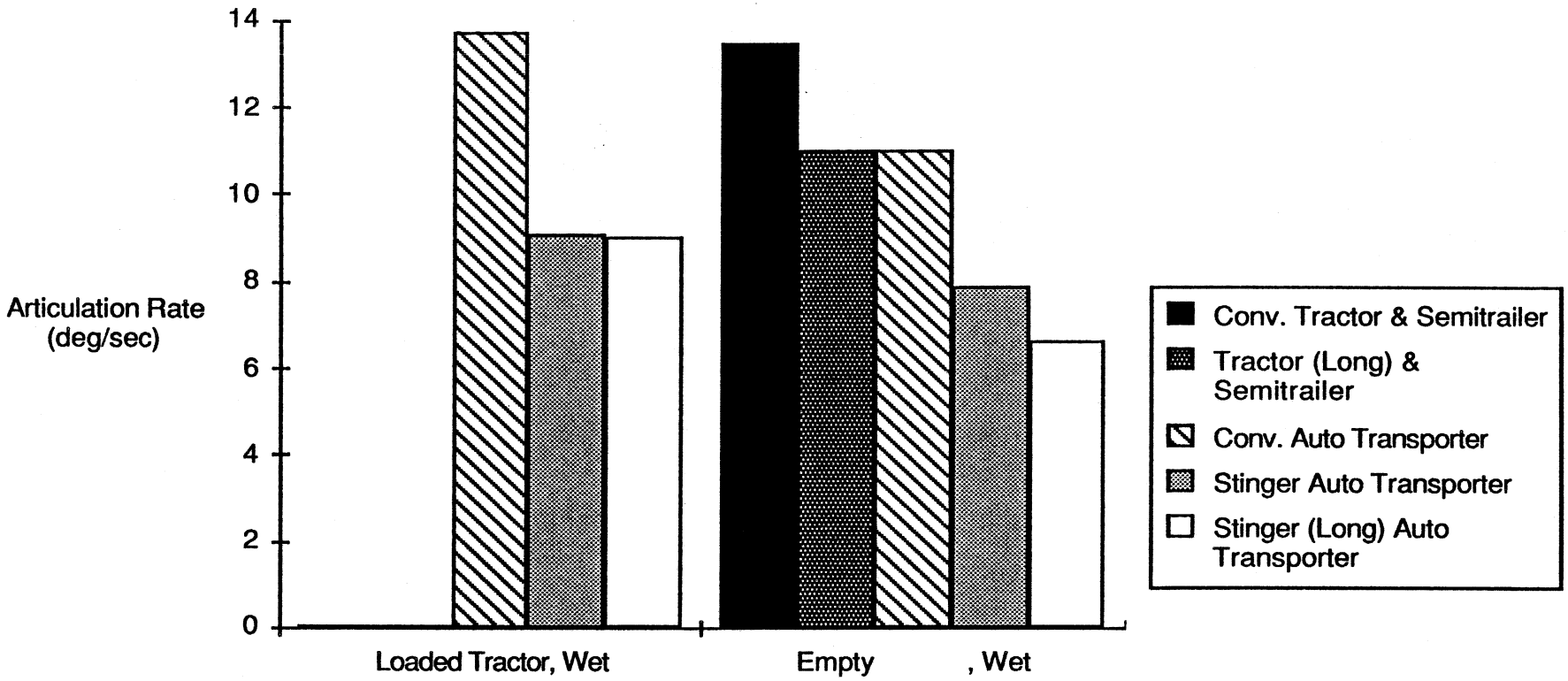


Figure 8

Braking on all wheels