TRUCK TIRE HYDROPLANING -

EMPIRICAL CONFIRMATION OF HORNE'S THESIS

by

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On September 6, 1984, the test trailer, "Myth Buster #1" was pulled down the hydroplaning trough at the Texas Transportation Institute's Proving Ground. With an inflation pressure of 75 psi at a speed of 58 mph, the spin velocity of the tire visibly decreased, a definite indication of dynamic hydroplaning. With that observation, the recent predictions of Walter B. Horne, the retired NASA engineer and scientist, and foremost authority on pneumatic tire hydroplaning, were confirmed. Totally destroyed was a myth that had evolved over the past 20 years, and was widely accepted by the scientific community; i.e., "Truck tires do not hydroplane".

There were several reasons, although none valid, why this myth developed. "In the early '60's, Horne and his fellow engineers in NASA discovered and studied the phenomenon of hydroplaning as it related to aircraft tires. Because of the way aircraft tires are constructed, the shape of the contact patch (that portion of the tire actually in contact with the ground) remains much the same for a fairly wide variation of tire load. The NASA group found that one could predict hydroplaning speed as a simple function of tire pressure. This relationship predicted hydroplaning speed of tires with 60 to 100 psi inflation pressure well above what could be achieved by highway vehicles. Since truck tires normally required pressures in this range, it was felt that they would not be subjected to speeds high enough to hydroplane. Further work in the late '60's on automobile tires confirmed that hydroplaning speeds would be extremely high at high levels of tire pressure. These studies of automobile tires, including testing by Stocker, Gallaway and Ivey at TTI, pointed to tire loads as being an unimportant variable. The following was not appreciated. While an automobile tire for a 4000 lb. vehicle may have a normal range of loads from 800 to 1200 lbs., a truck tire may be operated with loads varying from 600 to 6000 lbs. With this extremely wide load variation, the aspect ratio of a truck tire surface contact zone varies spectacularly, leading to hydroplaning conditions for a lightly-loaded, albeit normally inflated, truck tire at speeds common to highway vehicles. The aspect ratio is the ratio of the surface contact zone width to length."

At the Transportation Research Board's annual meeting in January of 1984, it was suggested to Committee A2B07 (Surface Properties-Vehicle Interaction) that a Task Group be set up to look into the special problems of tractor-trailer loss of control. Walter Horne attended that meeting. During the course of committee discussion, Horne disclosed that he had written a paper predicting that truck tires in an extremely low load condition will hydroplane at highway speeds and explained why this should occur. Horne was asked if this theory had been experimentally verified, since it was definitely contrary to "conventional wisdom". Horne responded that it had not been so verified. Shortly after that meeting, Horne sent Texas Transportation Institute (TTI) a copy of his forthcoming paper, scheduled for presentation at the meeting of ASTM E-17 in April.. Horne's arguments, explanations and predictions were compelling. Intrigued by the possibility of explaining why unloaded tractor-trailers are so prone to loss of control during wet weather, engineers at TTI were inspired to construct the test trailer "Myth Buster #1".

The test trailer and towing unit are shown in Figures 1 and 2. The hydroplaning trough is shown in Figure 3. The tire subjected to test is shown in Figure 4. All test data is shown in Table 1.

At this time, only four data points have been determined. The lightest load available on the test tire was 940 lbs. By imprinting the tire footprint (contact area on pavement surface) using carbon paper, it was determined that the aspect ratio (the nominal ratio of the footprint width to length) was 1.4 for tire pressure varying between 20 and 100 psi. This footprint is shown in Figure 5 at an inflation pressure of 75 psi.

By gradually increasing speed, the speed was determined, for a particular load, pressure condition, at which the tire began to spin down. That point was a reduction of tire speed of 2 mph. By increasing speed beyond that point, large values of spin down could be achieved.

TABLE 1 - TABULATION OF TEST CONDITIONS

Tire	Wear Condition	Pressure psi	Load lbs.	w/l	Hydroplaning Speed mph
Truck					
10.00.20	New	20	940	1.40	43
"	Worn*	40	940	1.40	51
"	"	75	940	1.43	58
"	"	100	940	1.41	62
"	"	70	3600	0.95	Over 62**
"	"	100	3600	1.10	Over 62**

Water depth about 1/4 inch $\pm$ 0.1 in.

* Worn to approximately 2/32 in. tread remaining

** 62 was the top speed achievable. No spin down was detected at this speed.

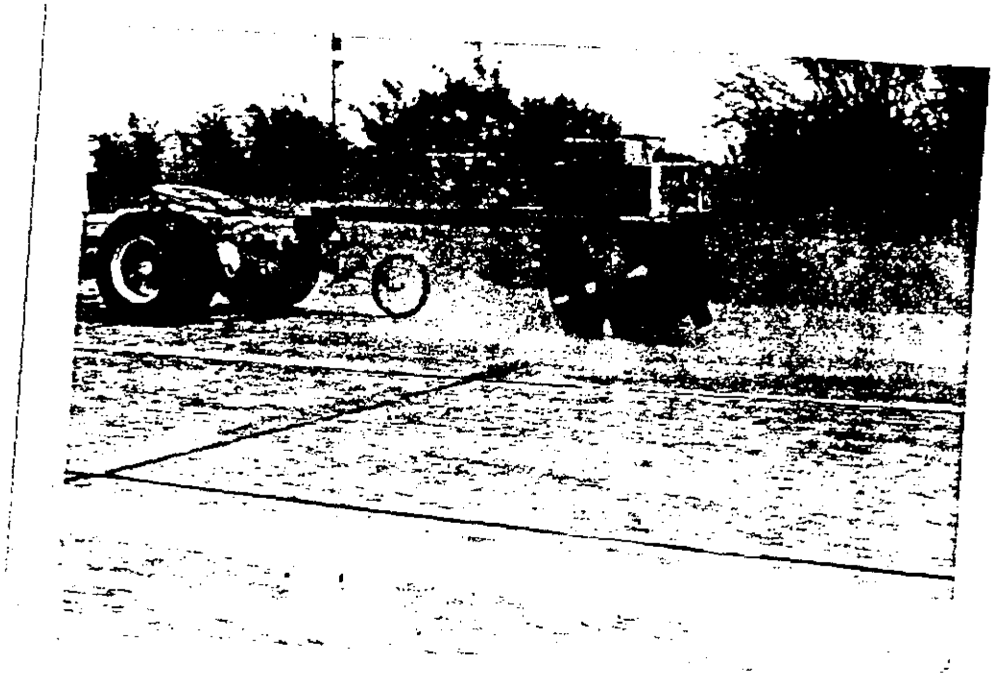

Figure 1 - Test trailer exiting hydroplaning trough. Note fifth wheel on tractor towing unit for accurate speed measurement.

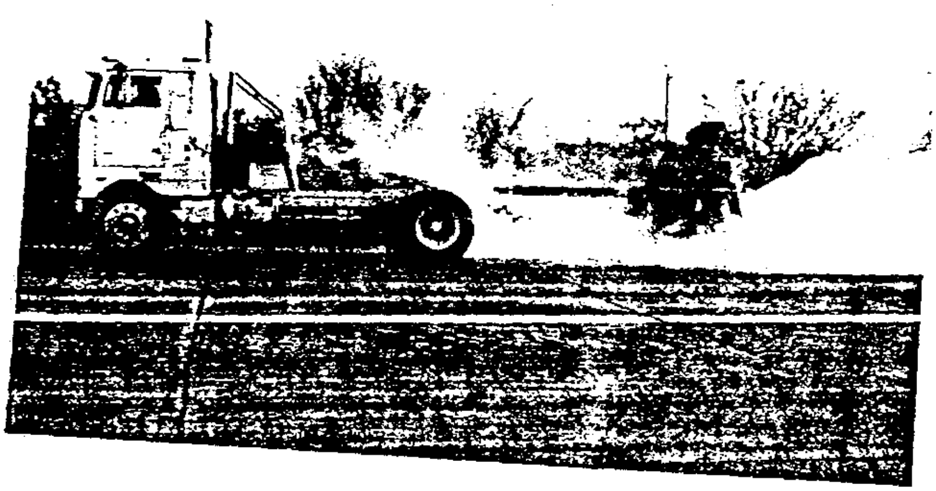

Figure 2 - Tow arrangement. Tractor straddles trough and left side trailer wheel runs in center of trough.

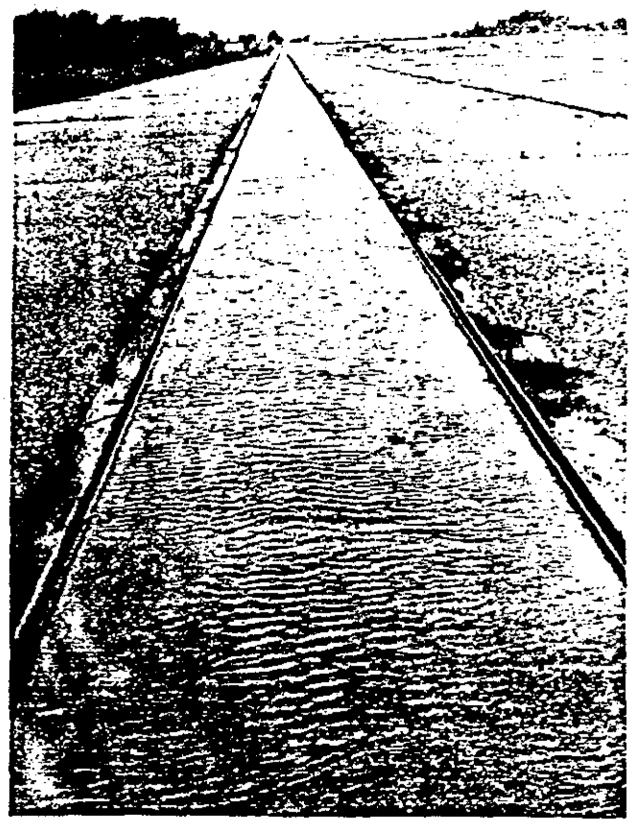

Figure 3 - Hydroplaning trough. Water depth was about 1/4 inch $\pm$ 0.1 inch.

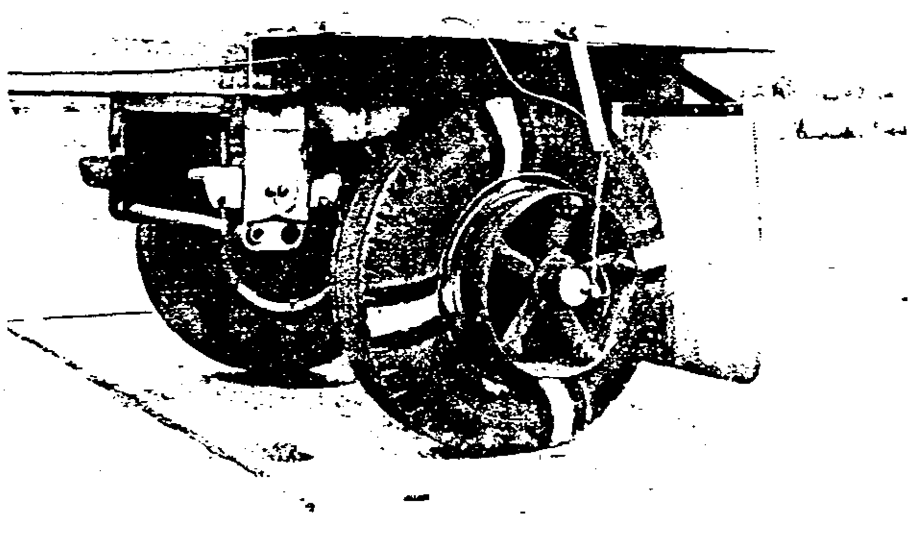

Figure 4 - Well-worn truck tire. Only two grooves have significant remaining depth.

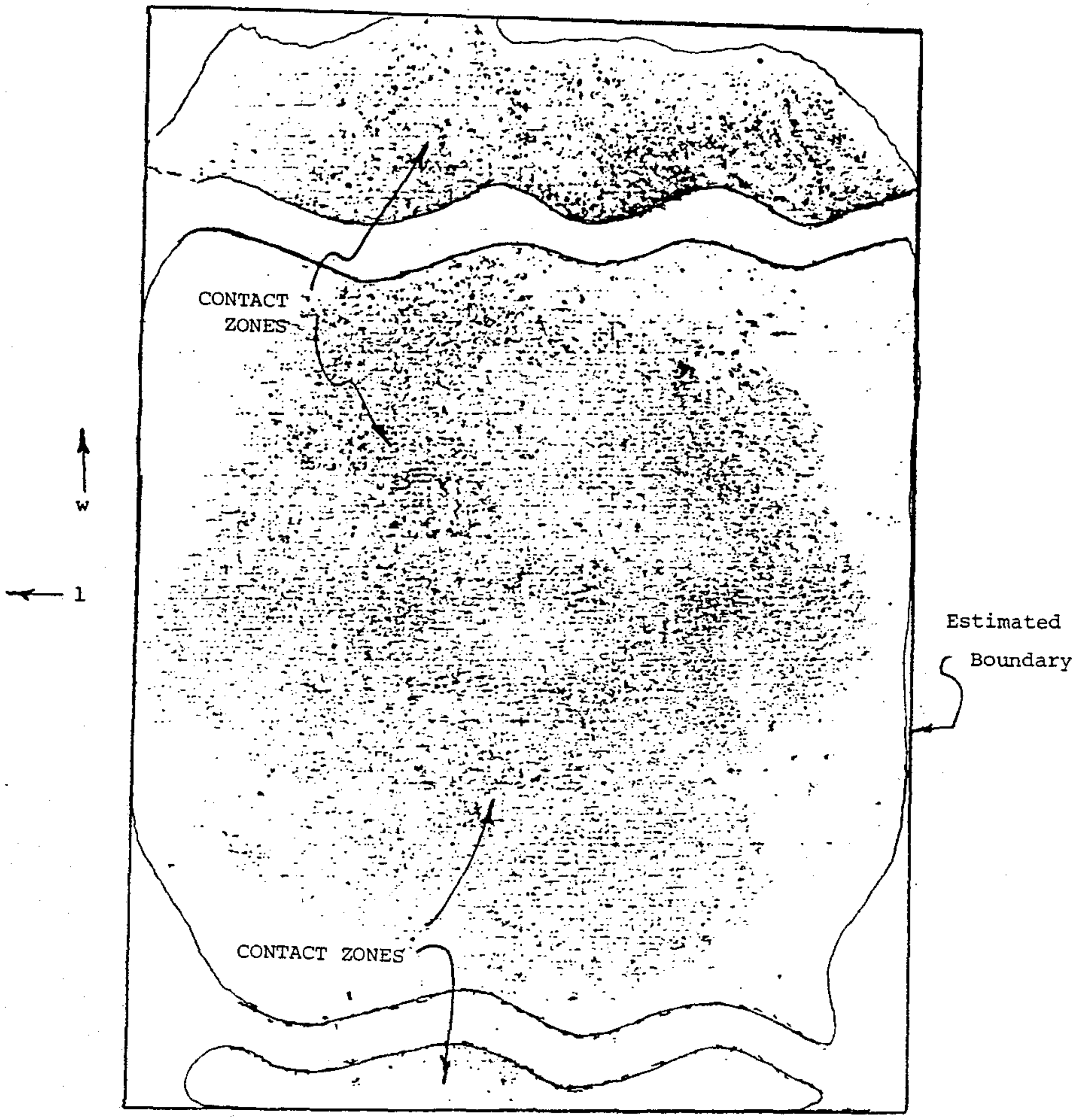

Figure 5 - Footprint of 10.00 20 truck tire at a load of 940 lbs. and inflation pressure of 75 psi.

Figure 6 shows how the four data points compare to Horne's predictions. Within the range of practical truck tire pressures, 60 to 120 psi, the comparison appears quite good. Horne's prediction is about four mph low (8%) at 60 psi, correct at 75 psi and about 6 mph (10%) high at 100 psi. Since there was no replication of the data achieved, this is probably within the range of experimental variation if such factors as tire construction, tire tread depth, water depth and pavement texture are considered.

The test data indicates the slope of the curves may be slightly lower than given by Horne's predictive equations. Richard Zimmer of TTI's Proving Ground found a curve fit of the four data points using an exponent for the tire pressure of 0.21, compared to the 0.5 used by Horne.

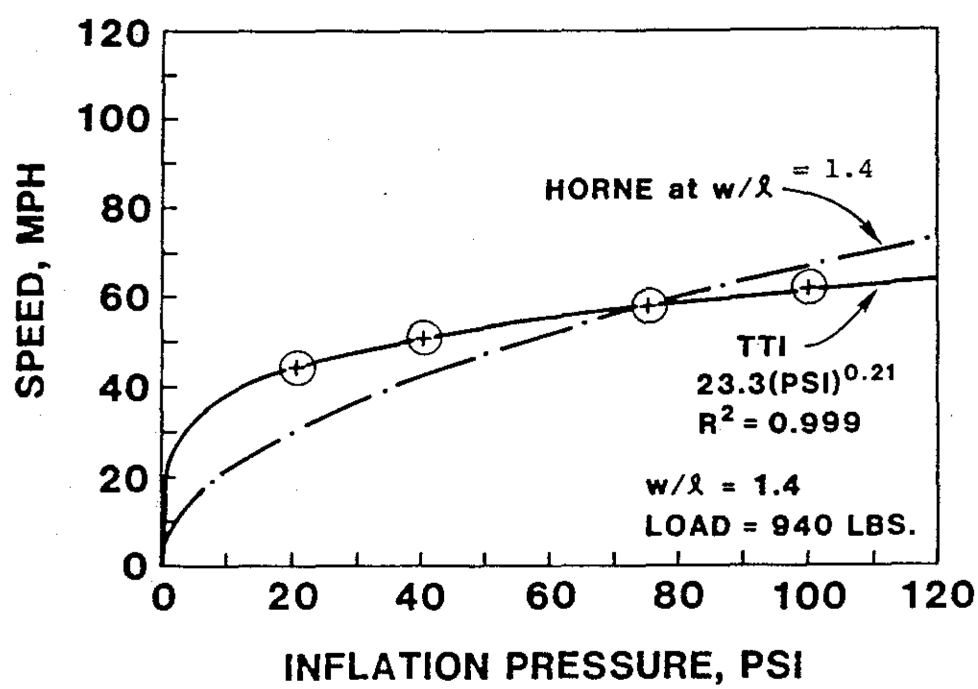

Figure 6 - Comparison of TTI data points and Horne's predictions at w/l = 1.4.

Horne's equation is

$$VEL = 7.95\,(P)^{0.5}\left(\frac{1}{w/\ell}\right)^{0.5} \tag{1}$$

compared to an equation based on Zimmer's curve fit, normatized at the test aspect ratio of 1.4

$$VEL = 23.3\,(P)^{0.21}\left(\frac{1.4}{w/\ell}\right)^{0.5} \tag{2}$$

A comparison of the curves achieved using the two equations is given by Figure 7. It must be considered highly presumptious to base an equation of four data points. During the next few months, TTI will acquire more data at lower and higher tire loads. This new information should allow the formation of a more reliable predictive. In the meantime, it must be concluded that Horne's theoretical predictions are reasonably accurate and that lightly loaded truck tires do hydroplane.

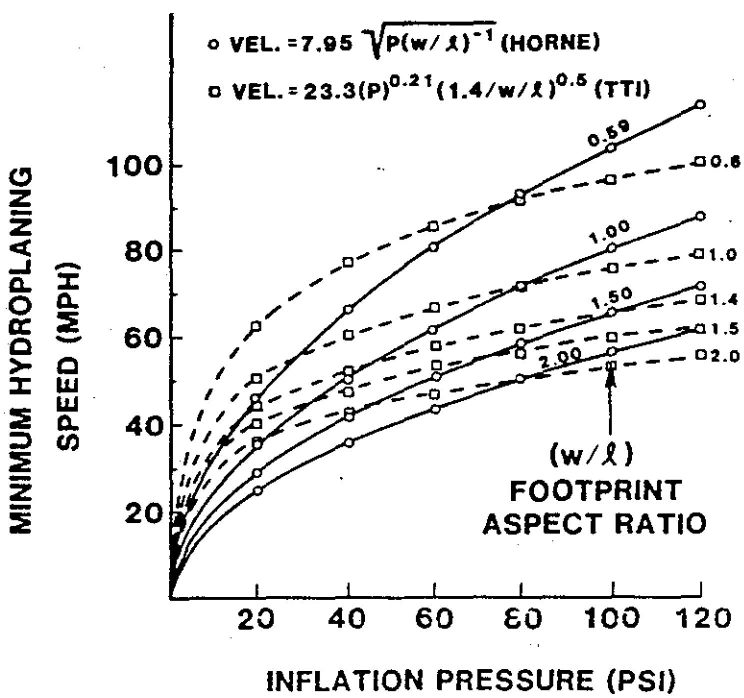

Figure 7 - Comparison of Horne's and TTI's curves.

This confirmation of truck tire hydroplaning may prove a vital element in understanding tractor-trailer losses of control in wet weather. TTI staff members in cooperation with Walter Horne are planning to do more definitive research in this area in 1985.

Finally, a toast is offered to Walter Horne (Figure 8), a man of foresight and talent, for his prediction of truck tire hydroplaning before performing a single test, from the test crew at TTI (Figure 9).

Figure 8 - A toast to Walter Horne

Figure 9 - The TTI Proving Ground
Test Crew