

Sway Stability of 5TH Wheel RV Trailers

Richard H. Klein

Richard Klein Consulting Engineers

Peter Broen

Dynamic Research Inc

Tim Schlabach

Keystone RV Company

ABSTRACT

This paper presents trailer sway testing results of a 5th wheel RV toy-hauler being towed by a conventional “dually” pick-up. Tests were performed at various speeds, trailer gross weights, king pin weights, and tire pressures. Results validate the understanding that 5th wheel trailers, at 20% pin weight generally have substantially better sway damping than conventional trailers. Tests at 10% pin weight show trailer sway damping is substantially reduced, but still is well above minimum industry accepted standards. Much of the improved sway damping for 5th wheel trailers can be attributed to the forward hitch location and not just the higher hitch loads that are typically used. What this means is that, although the recommended hitch load for a fifth wheel trailer is typically 20% or more, the sway response of the combination may be acceptable with substantially lower hitch loads, and they may maintain acceptable stability when the tow vehicle to trailer weight ratio is substantially less than 1:1, which does not generally occur with conventional travel trailers.

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INTRODUCTION

Fifth wheel and gooseneck trailers have long enjoyed the reputation of having virtually no trailer sway issues. It is well understood that trailer sway is less acute when the trailer center of gravity is well forward of the trailer axle as observed by percentage of trailer weight supported by the coupling. Fifth wheel and gooseneck trailers typically carry 20-25% of their weight at the tongue, or king-pin, and this contributes substantially to their favorable sway stability. Another factor that influences sway stability is the location of the coupling. There exists a location along the longitudinal axis of the tow vehicle called the “Tow Vehicle Neutral Steer Point.” At this location, lateral forces applied to the tow vehicle do not cause any tow vehicle yaw motion. The location of this point is determined by the relative front to rear tire cornering stiffness values for the tow vehicle. While the location of the Neutral Point will vary depending on such factors as vehicle loading and tire inflation pressures, this point will always be well forward of the tow vehicle rear axle. Moving the coupling location closer to the Neutral Point will reduce the tendency for trailer sway. The Neutral Point is

also that point where the coupling loads acting on the tow vehicle will not change its lateral acceleration steering gain ([Ref 2](#)). Moving the coupling location rearward tends to increase the lateral acceleration steering gain (Bundorf 1967 - [Ref 2](#)) which results in reduced understeer. The significance of this connection point as it relates to tow vehicle steer response is discussed in [Ref 2](#) and further as it relates to trailer sway response in [Appendix C](#).

The forward hitch location of a fifth wheel trailer provides a win-win situation for the user. The forward position allows higher hitch loads to be used while still maintaining favorable steering response and these higher hitch loads are known to reduce trailer sway tendency. Additionally, the forward hitch location itself, even without changing hitch load, will contribute to reduced trailer sway tendency.

What this means for the user is that, theoretically, these trailers can be successfully towed by vehicles weighing significantly less, ratio wise, than conventional travel trailers. For example, in conventional towing, when the tow vehicle to trailer weight ratio gets less than 1:1 (trailer weighing more than tow vehicle) trailer sway becomes an increasingly bigger

problem since the range of acceptable hitch loads (between too heavy and too light) gets very narrow. Past studies for the National Highway Traffic Safety Administration (NHTSA) ([Ref 1](#)) and SAE Technical Papers starting as early as 1967 ([Ref 2](#)) and continuing into the 70's ([Refs 3](#) and [4](#)) showed that hitch loads too high resulted in tow vehicle over-steer, and hitch loads too low resulted in excessive trailer sway. A review of the [Ref 1](#) work, showing the relationship between tow vehicle to trailer weight ratio, hitch load, and tow vehicle and trailer stability was recently published by the National Association of Trailer Manufacturers (NATM) in "The Trailer Handbook" ([Ref 5](#)), and presented at a Recreation Vehicle Industry Association (RVIA) seminar ([Ref 6](#)).

On the other hand, with regard to 5th wheel towing, there have not been any published reports or technical papers with regard to the effects of pin weight on trailer sway stability and/or tow vehicle understeer stability. Furthermore, the design of today's RV toy-haulers has the bulk of the cargo carried aft of the trailer axles. This means that the king pin weight will become less as cargo is added in the "garage" area. In fact, with some slide-out models, the fresh water tank is also located aft of the axles. Therefore, when loaded with maximum cargo in the garage area and a full fresh water tank, these trailers can have a pin weight percentage that is significantly less than the 20-25% that is typically recommended by the trailer industry.

The SAE Tow Vehicle Trailer Rating Committee, in their development of SAE J2807 ([Ref 7](#)), has qualitatively tested 5th wheel and gooseneck trailers at 20% pin weight but the effects of lower than recommended pin weights have not been investigated. The primary concern in matching a tow vehicle to a 5th wheel trailer (up until the development of SAE J2807) has been that the tow vehicle's Gross Vehicle Weight Rating (GVWR) and Rear Gross Axle Weight Rating (RGAWR) can support the pin weight, and that the engine has sufficient horsepower for towing (per the Owner's Manual). However, it is now of interest to determine what the effect of lower than normal pin weights and some of the other consumer variables, such as trailer overload and tow vehicle and trailer tire pressure, have on the 5th wheel trailer sway damping.

With this goal in mind the Keystone RV Co. organized an instrumented vehicle test program which was conducted at the Transportation Research Center (TRC) in East Liberty, OH in April 2011. The trailer was a Keystone "Fuzion" a 5th wheel, triple axle, toy-hauler with a Gross Vehicle Weight Rating (GVWR) of 18,000 lbs. The tow vehicle was a Ford F-450 with a GVWR of 14,500 lbs. and a tow rating of 24,000 lbs. The trailer sway damping testing was accomplished using accepted industry practice, including use of an automatic vehicle controller (AVC), and data was recorded using state-of-the-art in-vehicle instrumentation furnished by Dynamic Research Inc. (DRI) of Torrance, CA. This paper presents the results of this testing, and the conclusions that can be derived there from.

A complete description of the test vehicles and instrumentation is included in [Appendix A](#).

TEST PROGRAM

Trailer sway damping testing was performed using the "pulse steer" test procedure specified in SAE J2664 ([Ref 8](#)). This recommended practice specifies the combination vehicle (CV) speeds, steering wheel inputs (magnitudes and durations), allowable trailer articulation angles, and recommended data reduction procedures. To minimize the tow vehicle to trailer weight ratio the F-450 tow vehicle was tested at its minimum weight condition; that is with the only the driver and instrumentation, plus the 5th wheel weight. This resulted in a maximum loaded weight of 12,680 lbs. The combination was tested at the following trailer loading and tire pressure conditions:

- Empty condition, at 20% pin weight,
 - Nominal tire pressures
- Full GVWR of 18,000 lbs. at 10% pin weight,
 - Nominal tire pressures
 - Reduced tow vehicle tire pressures
 - Reduced tow vehicle and trailer tire pressures
- Overloaded (by 10%) condition, at 10% pin weight.
 - Reduced tow vehicle and trailer tire pressures

The ballasted conditions were accomplished by using sandbags located primarily in the rear garage area (brought to the limit of 2500 lbs.) and then as necessary throughout the trailer to obtain the desired pin weight. [Appendix A](#) documents the weights at each loading condition. As noted above, the OEM recommended tow vehicle tire pressures, both front and rear, were then reduced by 20 psi (fronts from 85 psi down to 65 psi, and rears 75 psi down to 55 psi.), and then the trailer tire pressures were reduced by 30 psi (80 down to 50 psi); all in a cumulative manner. Tests were conducted at target speeds of 45, 55 and 62 mph (72, 89 and 100 km/h). Recommended minimum levels of trailer sway stability can be found in [Ref 1](#) (0.15 damping ratio at 55 mph) and [Ref 7](#) (0.10 damping ratio at 62 mph). It should be noted that the more recent testing conducted for [Ref 7](#) was conducted with multiple test drivers, using a subjective rating scale. They found that a damping ratio of less than 0.10 at 62 mph (100 km/h) represented excessive trailer sway and was unacceptable.

A complete Test Run Log of all the test runs is presented in [Appendix B](#), which includes the target and actual speed of the test, the amplitude and direction of the pulse steer input, the trailer condition (including pin weight percentage) and then the resulting trailer sway response damping ratio, and damped natural frequency.

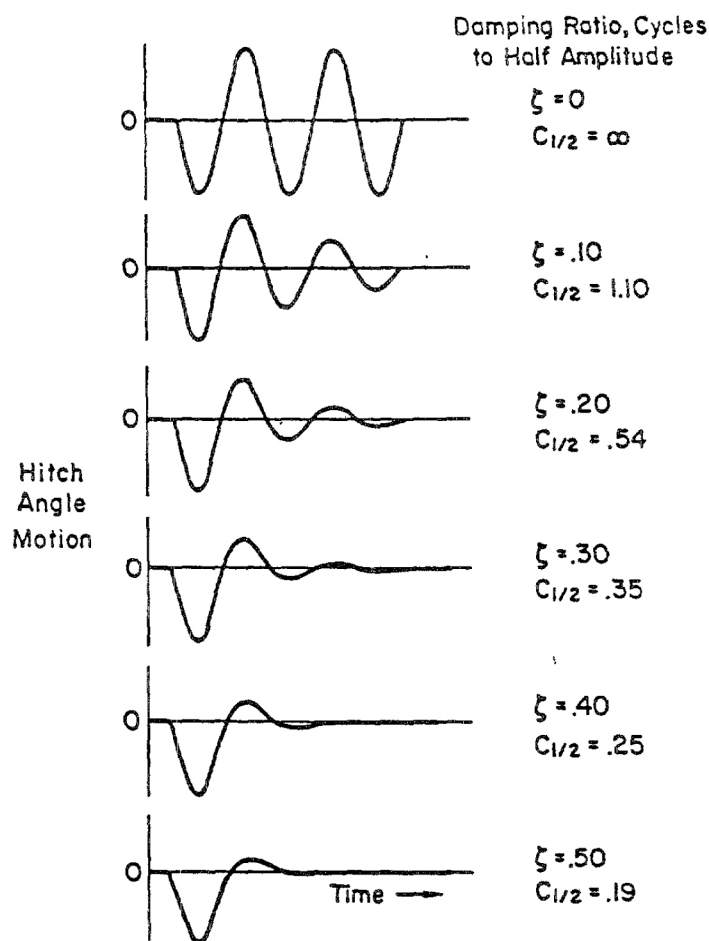


Figure 1. Second order system initial response characteristics

For reference, Figure 1, which was taken directly from Ref. 3, presents examples of what the trailer articulation time response would look like at different levels of “damping ratio.”

RESULTS

The results shown in Appendix B can be graphically summarized as shown in Figure 2.

In summary, when the left and right pulse steer results are averaged together, and equivalent data sets are compared, the following results can be observed:

1. For the empty trailer (14,770 lbs.) at 20% pin weight, sway damping is >0.40 for all speeds 45-62 mph. Damping ratios this high make any trailer sway almost imperceptible to the driver. In fact, damping ratio is difficult to calculate from articulation angle time responses at this level (refer back to Fig. 1). It should be noted that the actual tow vehicle to trailer weight ratio at this condition was 0.66. Based on the GVWR of the tow vehicle, rather than the tested weight, the weight ratio is less than 1:1.

2. For the fully loaded trailer (18,000 lbs.) at 10% pin weight, sway damping at 55 mph and 62 mph exceed the minimum recommended in Ref 1 and 7 by at least 100% (0.30 vs. 0.15 at 55 mph, and 0.24 vs. 0.10 at 62mph).

3. Overloading the trailer by 10% reduced sway damping by 23% (.274 down to .211) at 62 mph. However, this level of sway damping is more than double the minimum acceptable per Ref 7 of 0.10 @ 62 mph (100 km/h).

4. The loss of trailer sway stability (reduction in damping ratio) with increasing speed is higher (steeper negative slope) than is typically seen with conventional trailers, going from 0.29 @ 56 mph down to 0.21 @ 63 mph.

5. Reducing trailer tire pressure 30 psi (80 to 50psi) had no significant effect on sway damping at 62 mph (100 km/h).

6. Reducing truck tire pressure by 20 psi (F&R) improved sway damping by 13% (0.24 to 0.27 at 63 mph). This result is unexplained; however since the sway damping is more than double the minimum acceptable the differences are inconsequential.

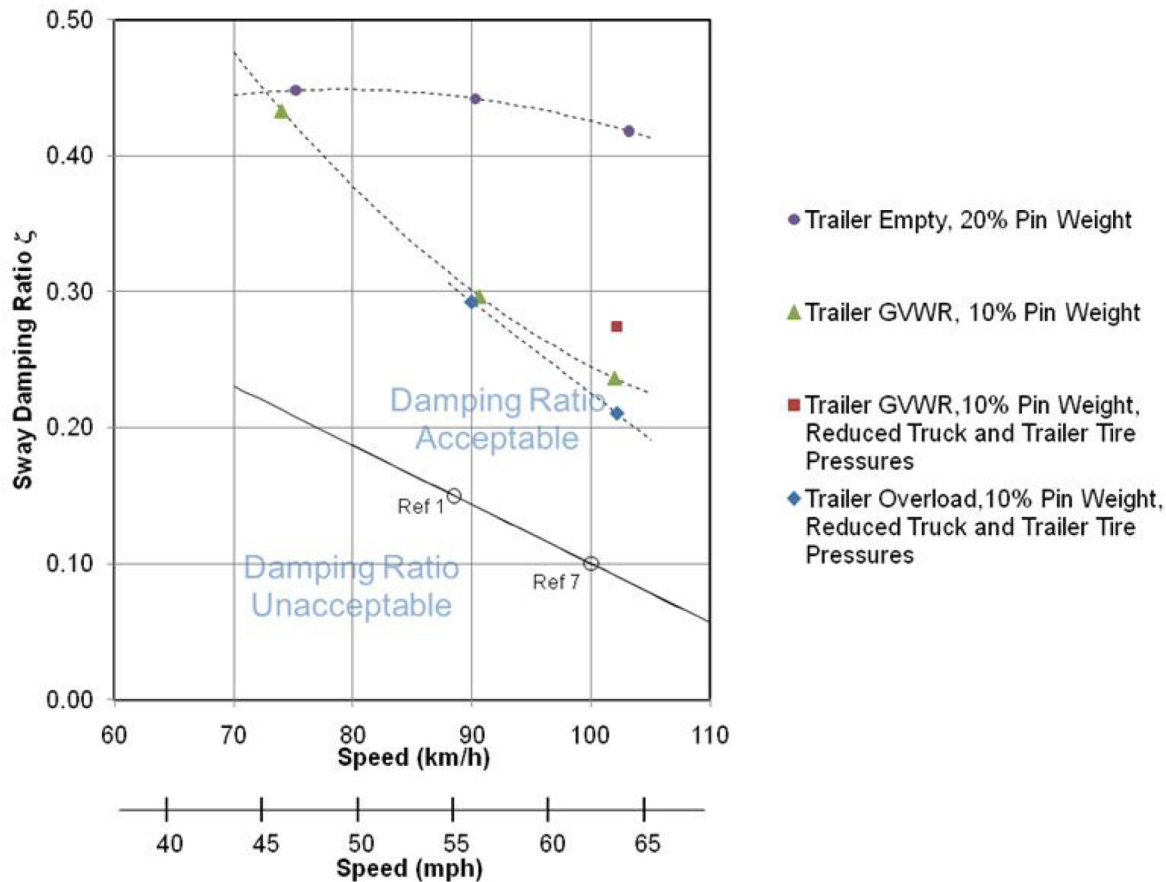


Figure 2. Trailer Damping Ratio vs. Speed for Key Test Conditions

CONCLUSIONS / RECOMMENDATIONS

For a typical trailer/tow vehicle combination, moving the hitch location forward on the tow vehicle has the effect of improving trailer sway stability in two ways. Firstly, the forward hitch location allows substantially higher hitch loads to be used while still maintaining acceptable steering response. Secondly, for a forward hitch location (closer to the neutral point), the trailer sway mode will have less tow vehicle rotational motion and this tends to provide higher damping ratios. For a further technical discussion of the basis of this result, refer to [Appendix C](#). For a conventional travel trailer, optimum hitch load is typically determined by balancing trailer sway and tow vehicle understeer response factors. In general, and as described previously in [Refs 1, 2, 3, 4, 5, 6, 7](#), the acceptable hitch load range is limited at the high end by tow vehicle steer response and at the low end by trailer sway response. As the weight of the trailer approaches that of the tow vehicle (e.g. a 1:1 weight ratio), the range of acceptable hitch loads becomes smaller.

Recommended pin weights for 5th wheel trailers are typically 20-25%. Based on the analysis and test results presented, the acceptable hitch load range may be much

wider than the recommended range. As shown in the case of the specialty (toy hauler) trailer studied, pin weights as low as 10% provide acceptable trailer sway stability at highway speeds. This is a very good result, since for trailers such as this where relatively heavy objects are typically loaded aft of the trailer axle(s), it is difficult to stay within a narrow range of pin weights (e.g., 20-25%). Furthermore, when compared to traditional bumper pull travel trailers, the fifth wheel trailer configuration allows for considerably greater loading flexibility while maintaining adequate sway resistance and tow vehicle steering response. This was demonstrated at pin weights as low as 10%.

Tow vehicle to trailer weight ratios less than 1:1 are achievable without trailer sway stability or steering response problems for 5th wheel trailers, given that the pin weight percentage is maintained within the manufacturer's recommended range, the tow vehicle is "rated" (by the OEM) to tow the trailer at full GVWR, and that the combination is not driven above 65 mph. This limit comes from the use of ST (Special Trailer) tires, which are speed limited to 65 mph.

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CONTACT INFORMATION

Richard H. Klein, P.E.
 Richard Klein Consulting Engineers
 13010 W. Castlebar Dr.
 Sun City West, AZ 85375
 623-748-8384
richardklein3@cox.net

Tim Schlabach
 Keystone RV Company
 2642 Hackberry Drive
 Goshen, IN 46526
 574-535-1912
schlt@keystonerv.com

Peter Broen
 Dynamic Research Inc.
 355 Van Ness Ave #200
 Torrance, CA 90501
 310-212-5211
pcb@dynres.com

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