An Engineering Guide for Trailer Safety Chain Installation, Attachment and Use

A Guide for Manufacturers, Distributors, and End Users

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I. Purpose and Scope

While there are many factors which contribute to safe or unsafe towing of trailers, this paper is focused on safety chains and their attachments to the trailer.[1] For information on other considerations for safe towing that are not addressed in this paper, please follow the instructions from your tow vehicle and trailer manufacturers and ensure that you know and understand the ratings for each part of the towing system including truck, receiver, hitch, ball, safety chains, and trailer.

II. Trailer Background

There are approximately 27 million trailers registered in the United States.[2] It is likely that the total the number of trailers is actually significantly higher than that as that number does not include the 14 states that either did not report any trailer registrations, don't require registration or did not indicate the types of trailers registered. Also indicating that this number is likely very low is that there are 11.8 million recreational boats registered in the U.S. alone.[3] It would also not include the many trailers less than a certain GVWR that many states don't require to be registered. Pennsylvania uses computerized inspections and registrations[4] and therefore is able to get very good data. The State of Pennsylvania had the following numbers of trailers in 2009 and 2017:

Item	Year 2017	% of Total	Year 2009	% of Total
Trailer 3,000 pounds or less	656,252	51.72%	612,052	56.98%
Trailer 3,001 to 10,000 pounds	368,357	29.03%	289,726	26.98%
Trailer 10,000 pounds or more	244,185	19.25%	172,296	16.04%
Total Trailers	1,268,804	100.00%	1,074,074	100.00%
PA Total Motor Vehicles Registered	10,563,512	3.916%		
US Total Motor Vehicles Registered	269.7 million[5]			
PA Population in 2017	12,805,537[6]	3.931%		
US Population in 2017	325,719,178			

If the number of trailers per registered vehicle is the same nationwide as it is in PA (note this is very similar to the population percentage also) then there would be:

Trailer Type	PA 2017	US 2017 est.
Trailer 3,000 pounds or less	656,252	16,758,222
Trailer 3,001 to 10,000 pounds	368,357	9,406,460
Trailer 10,000 pounds or more	244,185	6,235,572
Total Trailers	1,268,804	32,400,510

[1] Disclaimer: This paper contains references from multiple sources. Alpine Engineering & Design, Inc. does not assume responsibility or warrant the accuracy of the collected contents of this document.

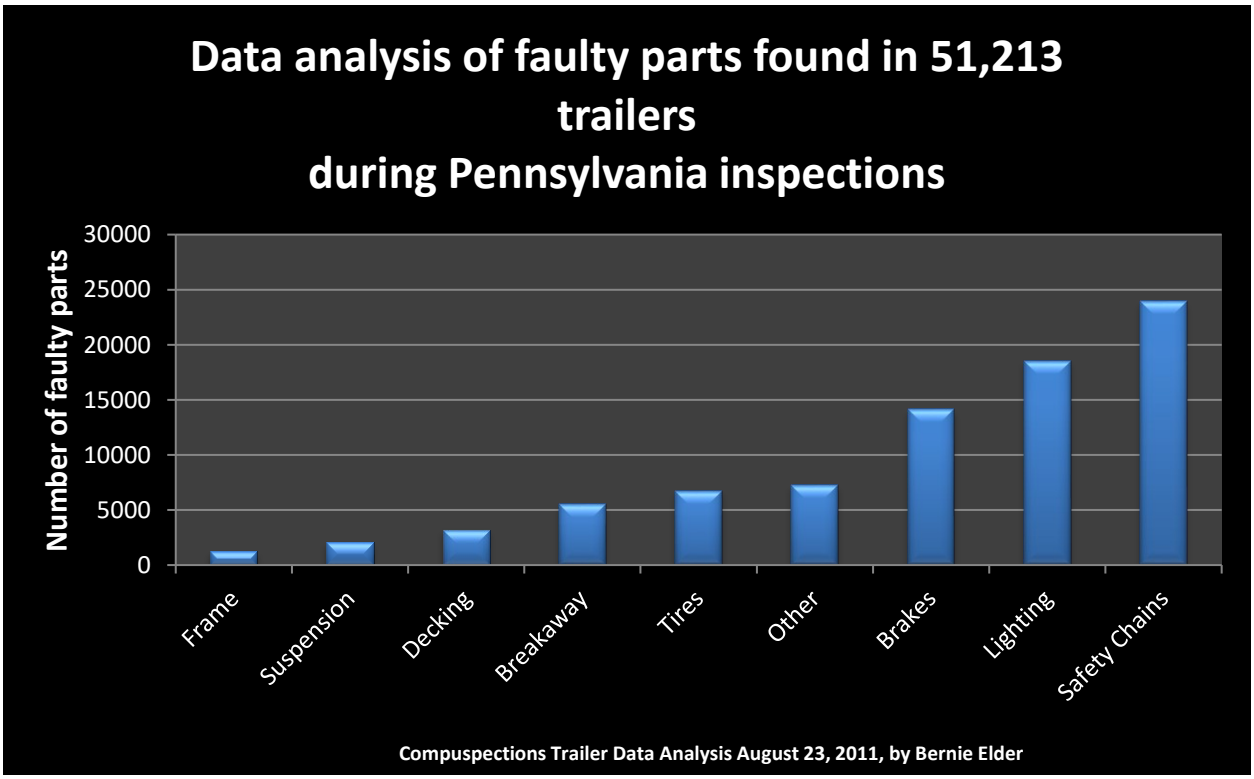
[2] Bureau of Transportation statistics, trailer and semi trailer registrations: 2012
[3] https://www.uscgboating.org/library/accident-statistics/Recreational-Boating-Statistics-2016.pdf, Table 38
[4] http://www.dmv.pa.gov/VEHICLE-SERVICES/Title-Registration/Pages/Annual-Report-of-Registrations-.aspx
[5] https://hedgescompany.com/automotive-market-research-statistics/auto-mailing-lists-and-marketing
[6] https://www.census.gov/data/tables/2017/demo/popest/state-total.html#tables

This 2017 number based off of the PA information is slightly over the 27 million trailers the Bureau of Transportation reported as registered in 2012. Even this is probably low as to the total number of trailers in the U.S., as many states do not require registration of trailers with a GVWR of less than 3000 pounds. Note that nearly ½ of all the trailers in PA are less than 3000 pounds GVWR.

Compuspections[7] used a computerized Safety Inspection Program in the State of Pennsylvania to collect data from required safety inspections of trailers in 2009. The Safety Inspection Stations inspected 51,213 trailers for safety issues with the frame, lighting, brakes, decking, safety chains, tires, breakaway switch system, suspension and other Miscellaneous. The following are the numbers of trailers that failed inspection due to the particular issue:

Item	# of Failures	% of Total
Frame	1,207	2.4%
Lighting	18,523	36.2%
Brakes	14,119	27.6%
Decking	3,201	6.3%
Chains	23,888	46.6%
Tires	6,716	13.1%
Breakaway system	5,472	10.7%
Suspension	2,013	3.9%
Other	7,202	14.1%

This can be visualized in the following graph:



[7] Compuspections Trailer Data Analysis, August 23, 2011, by Bernie Elder

Clearly, a number of the trailers had multiple items causing it to fail the safety inspection. By far the largest number of failures was due to the safety chains – nearly 50%! If this percentage was applied to the number of trailers registered nationwide, it would mean that nearly 15 million trailers in this country have a safety problem with the safety chains. The Compuspections report identified some of the failures as worn links, stretched links, cracked links, nicks/gouges, welded repairs, knots, attachment with quick links or other non-approved links and other non-approved repairs. The following are some examples of safety chain defects that caused failure of the safety inspection.

Examples of non-approved connections to the trailer (even if these were strong enough, they are not permanent connections). Most of these would also not be suitable for chain attachment to the tow vehicle either as their strength is less than the GVWR of the trailer:

Worn Chains:

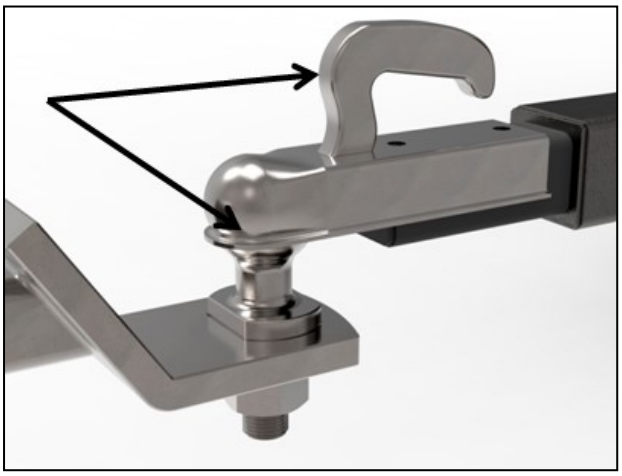
Reduced Strength:

We note that all of these safety inspection failures were about the chains themselves and did not address HOW the chains were hooked to the tow vehicle. If safety chains were the primary coupling system, nobody would stand for a nearly 50% failure rate.

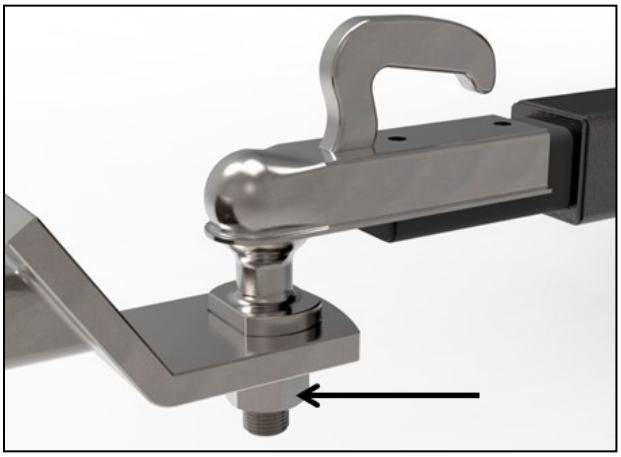
III. Trailer Safety Chain Background

Trailer safety chains are a secondary connection between the rear of the towing vehicle and the front of the trailer. This can be thought of as an added insurance that your trailer will not become detached from your tow vehicle should any part of the primary coupling fail. The following is a list of some of the possible primary coupler failures:

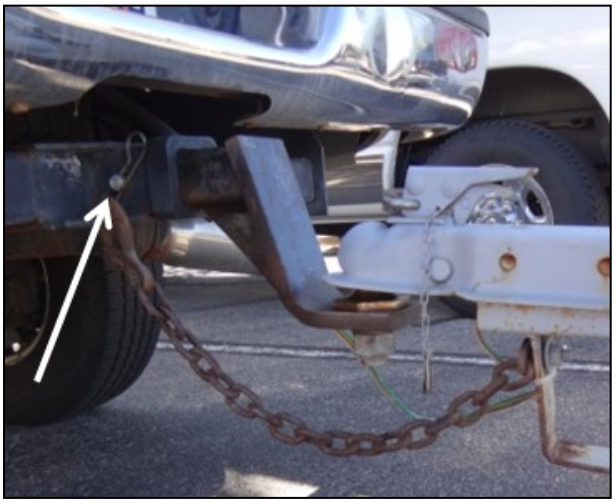
- The coupler can come off of the ball:
  - The coupler is not fully seated on the ball, such as when the coupler is latched and sits on top of the ball;
  - the latch on the coupler was not properly latched or becomes unlatched;
  - the wrong size ball for the coupler was used, or the ball was severely worn;
  - the underjaw (certain types of couplers only) is not properly adjusted;
  - there is a mechanical or structural failure of a coupler component.



- The ball can come off of the hitch:
  - The shank on the ball fails;
  - the nut holding the ball to the hitch comes loose.
  - the weld holding the ball to the hitch fails.



- The hitch can come out of the vehicle receiver:
    - The keeper pin was never inserted;
    - the R-pin holding the keeper pin in place was never inserted and the keeper pin falls out;
    - there is a structural failure of the keeper pin;
    - the keeper pin is makeshift (i.e. ¼" bolt, zip-tie, etc.)



- The coupler can become detached from the trailer draw bar:
    - Bolts holding the coupler to the draw bar of the trailer tongue come loose;
    - structural failure of the welds or bolts holding the coupler to the draw bar.

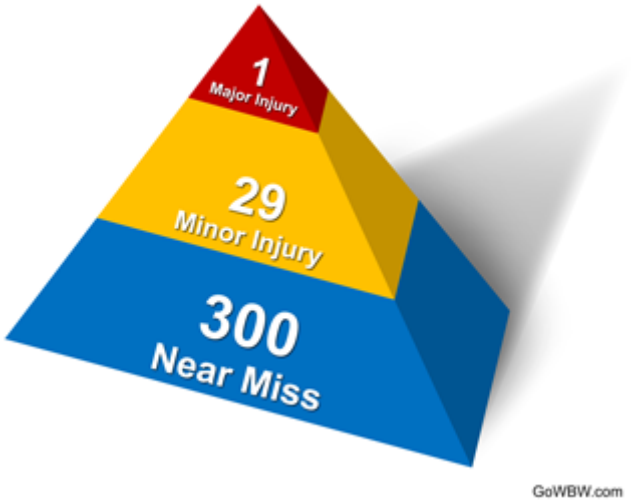
As can be seen from the above there are many modes of primary coupling failure. Some are a result of operator error, while others are due to a deficiency in design or strength of the coupling itself. Because there are so many failure modes with the primary coupling, even the most vigilant person can make a mistake. Perhaps someone was talking to the person coupling the trailer and he became distracted and forgot to latch the coupler. Perhaps inexperience allowed the coupler to be latched, but be sitting on top of the ball. The trailer can actually be towed in this condition for quite a long way if there is sufficient tongue weight, but it only takes a slight bump or dip to set the trailer free.

The dangers associated with trailers that become unhitched from their towing vehicles or what are sometimes called "runaway trailers" can be catastrophic as the following photos show:

The authors have been asked on many occasions to investigate trailer accidents and be expert witnesses in trailer lawsuits. When these "runaway trailers" come loose, they are like unguided missiles. Towed vehicles cause millions of dollars of damage, thousands of injuries, and many many deaths every year. In the ten years from 2006 through 2015 there were 3,407 fatal accidents involving towed vehicles (an average of 341 deaths/year). During that same time there were 120,368 injury accidents (an average

of 12,037 injury accidents/year. During that same time there were 401,989 property damage only accidents (40,199/year).[8]

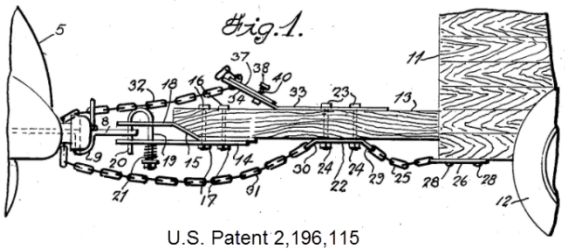
So…how big of a problem is trailer decoupling? It is not possible to track the frequency of trailers becoming decoupled from their tow vehicles since having a trailer decouple from the tow vehicle is not a reportable offence. However, The Los Angeles Times conducted research on major recorded incidents such as lawsuits and news reports which identified approximately 540 such crashes between 2000 and 2007.[9] As trailer decouplings that are not sensational or that end in a lawsuit would likely not be part of these Los Angeles Times "major" incidents, this number likely grossly understates the frequency of trailer decouplings. Accident theories have been developed to explain the relationship between near misses, minor injuries, and major injuries. One popular theory is the Heinrich 300-29-1 model, commonly known as the safety triangle which was corroborated by research done by the Insurance Company of North America.



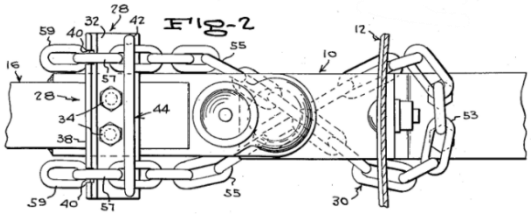
This theory states that for every one major incident, such as those reported by the LA Times, there are 29 minor incidents such as runaway trailers that do not collide with any people or do any major damage and 300 near misses, which may be considered decoupling incidents where runaway trailers were prevented by safety chains. If we consider the LA Times reported incidents as the top tier, under this theory there would have been approximately 162,000 near misses (decouplings) in the years between 2000 and 2007 or 20,250 decouplings/year. That is equivalent to a trailer decoupling incident every 26 minutes in the United States. As the number of trailers on the road has only increased since 2007, it follows that the number of incidents has also increased.

Auxiliary connections for trailers were introduced at least as early as 1939 as described in US Patents 2,225,130 and 2,196,115 and the configuration where two chains are crossed under the coupler, which has become the standard auxiliary connection, was seemingly introduced as early as 1959.

[8] See Exhibit 1.
[9] HAULING DANGER, COURTING DISASTER, By Myron Levin and Alan C. Miller, Los Angeles Times, December 12, 2007.



U.S. Patent 2,196,115



U.S. Patent 2,937,885

The purpose for the auxiliary safety connections as stated in these early patents is "to hold the trailer connected with the machine and on the road in case of injury to the usual hitch or loss of a coupling pin or the like."[10] Having a redundant system is a well-known method to considerably improve the overall safety. For instance, consider a first system that has a failure rate of 1 in 10,000 times it is used. Consider also a second system that has the same failure rate of 1 in 10,000 times. If these systems are used in parallel and if we assume that the events are independent, then the probability of both occurring at the same time is:

$$P(A \text{ and } B) = P(A) \cdot P(B)$$

Therefore the probability of both systems failing at the same time is 1 in 100,000,000. Thus, if a particular person forgot to latch the coupler 1 in 1000 times the trailer was pulled and also forgot to properly attach the safety chains 1 in 1000 times, he would only forget both 1 in a million times, if the events are actually independent.

The purpose of safety chains is to provide this redundancy for the primary coupling, to keep the trailer connected to the tow vehicle. In the event of a primary coupling failure, the safety chains should keep the trailer connected to the tow vehicle long enough to bring the trailer to a safe stop. As will be discussed subsequently, properly designed and attached safety chains greatly increase the probability of being able to control the trailer while bringing it stop. The chains are not meant to maintain the connection in the event of rollover, jackknife, collisions, etc.[11]

The Society of Automotive Engineers (SAE) has promulgated a safety standard (J684) for hitches and safety chains in an effort to increase the safety of towed vehicles. States have enacted laws with the intent to prevent or limit the number of runaway trailers as will be discussed below, however complete trailer decoupling continues to occur.

IV. Federal Trailer Chain Laws

Because of the dangers associated with runaway trailers, Federal laws have been put in place regarding safety chains for commercial vehicles. Commercial vehicles with respect to trailers are defined as:

> "Any…towed …vehicle used on a highway in interstate commerce to transport …property when the vehicle… Has a gross vehicle weight rating or gross combination weight rating, or

[10] U.S. Patent 2,225,130.
[11] See SAE J684-2005.

gross vehicle weight or gross combination weight, of 4,536 kg (10,001 pounds) or more." (49 CFR §390.5)

Interstate commerce means:

"Interstate commerce means trade, traffic, or transportation in the United States -
(1) Between a place in a State and a place outside of such State (including a place outside of the United States);
(2) Between two places in a State through another State or a place outside of the United States; or
(3) Between two places in a State as part of trade, traffic, or transportation originating or terminating outside the State or the United States." (49 CFR §390.5)

These safety chain laws for full trailer commercial vehicles are found in 49 CFR §393.70 (d) (1-5) and are reproduced below:

"(d) Safety devices in case of tow-bar failure or disconnection. Every full trailer and every converter dolly used to convert a semitrailer to a full trailer must be coupled to the frame, or an extension of the frame, of the motor vehicle which tows it with one or more safety devices to prevent the towed vehicle from breaking loose in the event the tow-bar fails or becomes disconnected. The safety device must meet the following requirements:
(1) The safety device must not be attached to the pintle hook or any other device on the towing vehicle to which the tow-bar is attached…
(2) The safety device must have no more slack than is necessary to permit the vehicles to be turned properly.
(3) The safety device, and the means of attaching it to the vehicles, must have an ultimate strength of not less than the gross weight of the vehicle or vehicles being towed.
(4) The safety device must be connected to the towed and towing vehicles and to the tow-bar in a manner which prevents the tow-bar from dropping to the ground in the event it fails or becomes disconnected.
(5) Except as provided in paragraph (d)(6) of this section, if the safety device consists of safety chains or cables, the towed vehicle must be equipped with either two safety chains or cables or with a bridle arrangement of a single chain or cable attached to its frame or axle at two points as far apart as the configuration of the frame or axle permits. The safety chains or cables shall be either two separate pieces, each equipped with a hook or other means for attachment to the towing vehicle, or a single piece leading along each side of the tow-bar from the two points of attachment on the towed vehicle and arranged into a bridle with a single means of attachment to be connected to the towing vehicle. When a single length of cable is used, a thimble and twin-base cable clamps shall be used to form the forward bridle eye. The hook or other means of attachment to the towing vehicle shall be secured to the chains or cables in a fixed position.
(6) If the towed vehicle is a converter dolly with a solid tongue and without a hinged tow-bar or other swivel between the fifth wheel mounting and the attachment point of the tongue eye or other hitch device -

(i) Safety chains or cables, when used as the safety device for that vehicle, may consist of either two chains or cables or a single chain or cable used alone;
(ii) A single safety device, including a single chain or cable used alone as the safety device, must be in line with the centerline of the trailer tongue; and
(iii) The device may be attached to the converter dolly at any point to the rear of the attachment point of the tongue eye or other hitch device.
(7) Safety devices other than safety chains or cables must provide strength, security of attachment, and directional stability equal to, or greater than, safety chains or cables installed in accordance with paragraphs (d) (5) and (6) of this section.
(8)
(i) When two safety devices, including two safety chains or cables, are used and are attached to the towing vehicle at separate points, the points of attachment on the towing vehicle shall be located equally distant from, and on opposite sides of, the longitudinal centerline of the towing vehicle.
(ii) Where two chains or cables are attached to the same point on the towing vehicle, and where a bridle or a single chain or cable is used, the point of attachment must be on the longitudinal centerline or within 152 mm (6 inches) to the right of the longitudinal centerline of the towing vehicle.
(iii) A single safety device, other than a chain or cable, must also be attached to the towing vehicle at a point on the longitudinal centerline or within 152 mm (6 inches) to the right of the longitudinal centerline of the towing vehicle.
[37 FR 21439, Oct. 11, 1972, as amended at 70 FR 48053, Aug. 15, 2005]

A few notes on the Federal Regulations may be of help here. First, the regulation quoted above applies only to full trailers [think red wagon type where none of the weight of the trailer (except the tongue) is supported on the tow vehicle]. Under federal law if some of the weight of the trailer is supported on the tow vehicle, the trailer is called a semi-trailer. (49 CFR §390.5) It is also of note that the interpretation of 49 CFR §393.70 has been interpreted by FMCSA as follows:

> "If the ultimate combined breaking strength of the **two** chains is equal to the gross weight of the towed vehicle(s), the requirements of §393.70(d) are satisfied. It should be noted that some States may have more stringent requirements for safety chains."

As noted in the next section, most states have more stringent laws that require **each** of the two safety chains to hold the GVWR of the trailer without failure. Some states also refer to 49 CFR §393.71 (h)(10) as a trailer safety chain regulation for their state. This federal regulation is actually for tow bars that attach to the front of a vehicle that allows it to be towed by another vehicle while riding on its own wheels.

V. State Trailer Chain Laws

The following is a summary of requirements of state trailer chain laws; the chart was prepared in order to examine how many states had a particular requirement. A state by state list of each state's safety chain law along with a citation to where the actual law can be found at www.linklock.net.

Requirement	Number of States that Require	SAE J684 Requirement	Other SAE J684 Requirements
No chains required.	11	--	**7.4 Chain assemblies for sale identified in the specs, packaging, the chain itself or catalog the class and GVWR**
One chain required.	18	**7.6.2 Single chain can be used provided it is permanently attached to each side of tongue.**	
Two chains required.	19	**7.5.1 Two chains permanently fastened to trailer.**	**7.5.1 Chains attach to hitch assembly with same strength as the chain.**
Chain strength - Maintain control if tow bar or hitch fails.	27	--	
Prevent Tow Bar from dropping to ground if disengaged.	20		
State requires chains only - no cables	16	**7.3 Wire rope can be used as a safety chain.**	
No more slack than for proper turning.	13	**7.5.2 No more slack than necessary to permit proper turning of the vehicles.**	
Chain strength at least equal to weight of the trailer & load.	9	**7.2 Breaking force for each chain is the maximum GVWR rating for the class trailer. 1 minute tested.**	
Chains must be crossed.	5	**7.5.2 The safety chains shall be crossed under the trailer tongue**	
Chains attached to side of tongue.	4	**7.5.1 Chains permanently fastened to the tongue, one on each side.**	
Chains same amount of slack/equal length.	4	**7.5.2 Safety chain connected so that the slack for each length of chain is approximately the same.**	
Positive safety connections.	4		

Must meet DOT or SAE Standards.	4	
Chain sufficient strength to haul loaded trailer.	3	
Chain attachment not use ball/coupling fasteners.	3	**7.5.3 Chains not attached to ball or fasteners that secure ball to hitch.**
Minimum chain/cable diameter 1/4".	2	
Attached equal distance & on opposite sides of CL.	2	
Cannot be welded to trailer.	1	**7.2 Do nothing to reduce the strength below the rating in Table 4 (welding, twisting, etc.)**

As can be seen above, many states have passed laws regarding safety chains. According to our research there are still 11 states that inexplicably still have no law in place regarding trailer chains. We will examine each of these laws and give our take of the reasoning behind them in the section entitled, Problems Meeting All the Laws.

VI. Standards and Manufacturer Recommendations

One "standard" in the industry is known as the V-5 standard is actually entitled Regulation VESC-5 and was promulgated by the Vehicle Equipment Safety Commission. The VESC promulgated 22 vehicle "regulations" from the late 60's through the early 80's, most of which have been replaced by Federal Motor Vehicle Safety Standards (FMVSS). The VESC is inactive and "has not met since 1983 due to long-term funding problems."[12] The V-5 standard was adopted in 1965 and was last revised March 1973. It has not been replaced by a FMVSS. The V-5 regulation states that its purpose "is to provide the states with a uniform minimum requirement for motor vehicle connecting devices and towing methods. It is designed to increase highway safety by reducing towing and hitch related accidents." The VESC files were transferred to the Automotive Manufacturers Equipment Compliance Agency (AMECA). The V-5 regulation can be found at http://vesc.org/vescregs.html. As will be shown below, a number of states utilized at least part of the V-5 regulation in their state law.

The Society of Automotive Engineers (SAE) in 1962 created and published SAE Standard J684 entitled: Trailer Couplings, Hitches, and Safety Chains—Automotive Type. This standard was last

[12] http://vesc.org/?page_id=27, last viewed March 1, 2018

updated in 2005, but was reaffirmed by SAE in 2014. SAEJ684 is very similar to the V-5 standard. SAE J684 states that it applies to:

> "couplings, hitches, and safety chains used in conjunction with all types of trailers or towed vehicles whose Gross Vehicle Weight Rating (GVWR) does not exceed 4540 kg (10,000 lb). This includes such types as utility, boat, camping, travel, and special purpose trailers which are normally towed by conventional passenger cars, light-duty commercial vehicles, light trucks, and multipurpose passenger vehicles"

Section 7 of the SAE J684 standard covers Safety Chains and includes subsections on:

- **Strength Requirements -** The standard requires that "each individual safety chain and all attaching means, shall meet the minimum breaking force tensile load" shown in the table below. The standard also states that any operation performed on safety chains subsequent to the chains manufacture cannot reduce the strength below that shown in the table.

Safety Chain or Trailer Classification	Breaking Force - Minimum
Class 1	2,000 lbs
Class 2	3,500 lbs
Class 3	5,000 lbs
Class 4	The strength rating of each length of safety chain or its equivalent and its attachments shall be equal to or exceed in minimum breaking force the GVWR of the trailer (Class 4 trailers have GVWR up to 10,000 lbs)

- **Wire Rope Thimbles -** When cables or wire ropes are used as safety chain, a thimble needs to be used to protect the wires of the rope from damage where it is attached.
- **Chain Application and Identification -** Chains should be marked by class of trailer and GVWR when available for sale.
- **Installation**
    - When trailer chains are installed on trailers, they should be permanently fastened to the trailer tongue, one on each side for a total of two chains.
    - A single chain may be used provided it is permanently fastened to each side of the trailer tongue so as to function as two separate chains.
    - The chains should be connected from the trailer tongue to the hitch assembly of the towing vehicle.
    - When connected, the slack for each length of chain should be approximately the same length when the vehicles are in a straight line.
    - There should only be enough slack to allow proper turning.
    - The safety chains should be crossed under the trailer tongue, which reduces the probability of stressing or breaking the chains when turning.

- Chains should not be attached to any part of the ball, or any fasteners that connect the ball to the hitch member. The V-5 standard also does not allow chains to be attached with the fasteners used to attach the coupling either.

- **Equivalency -** Other methods of auxiliary connections are not precluded, provided they will effectively maintain connection between the towing vehicle and trailer in the event of separation of the coupling from the ball or the ball from the hitch.

VII. Problems Meeting All the Laws

Even a casual look into state trailer chain laws show that there is no consistency from state to state. As mentioned above, eleven states have no trailer safety chain laws at all! Even though there are standards and laws on proper installation and use of safety chains, misuse and improper applications are very commonplace. There are a number of reasons that safety chains are not used correctly, including: ignorance, inexperience, lack of training, negligence, and improper or improper design of chains or attachments. In the case of most serious accidents, there are usually multiple problems with the way the trailer is connected to the tow vehicle that leads to injury and damage. Several of these state trailer chain laws are almost never met by the trailer towing public. Trailer manufacturers who should be most knowledgeable about trailer laws and generally manufacture their trailers to meet such laws have generally not designed the trailer chains in such a way to allow their end customer to easily meet those state laws.

In this section, the authors will identify many of the major state trailer chain laws and try to discern if possible the safety reason for that law.

Strong Enough to Maintain Control of the Trailer

Taken in order of the number of states that have the requirement, the most cited requirement is that the chain strength has to be enough to maintain control of the trailer if the tow bar or hitch fail. Although, this is ultimately what one would want the safety chains to do, it provides little guidance at to what that strength would need to be. Clearly, the strength needed would be dependent on a number of factors such as:

a. Do the chains get abraded on the ground when the primary coupling fails?
b. How much force is exerted on the chains if they are long enough to allow the tongue to sway from side to side?
c. Do the chains “maintain control” if they are long enough for the trailer to ram into the back of the tow vehicle when trying to stop?

d. How much force is generated if the trailer scraping along the ground hits a crack or a bridge expansion joint?

These are not easy questions to answer because of all the variables involved, but the forces generated on the chains are easier to control when other safety requirements are met as will be discussed below.

Keep the Tow Bar from Dropping to the Ground

The next most cited requirement requires the chains to prevent the tow bar from dropping to the ground if the primary coupling is disengaged. There are 20 states that have this requirement. In our experience, virtually no trailer coming from the manufacturer will meet this law when attached to all vehicles. A trailer manufacturer generally will put safety chains or cables on their trailers that are long enough to attach to a variety of vehicles, with a variety of hitches. Trailer chains that long will never keep the tongue from hitting the ground.

This requirement is also difficult to meet if the chain attachment to the trailer is too far back from the end of the coupler. To illustrate, let's say the chains are attached 2 feet back from the end of the coupler and they have an additional foot past the end of the coupler to allow for attachment to the tow vehicle (this is actually not even enough to attach to most vehicles), so the chains are 3 feet long. If the ball is approximately 20" off the ground (a pretty standard ball platform height), it does not take too much calculating to see that if the coupler detaches from the ball, the whole trailer can move forward and the 36" of chain will allow the tongue to drop to the ground. We have actually designed a formula for estimating whether, given certain parameters, the chains will support the tongue from hitting the ground. This can be found at www.linklock.net. Having the chain attachment nearer to the end of the coupler makes abiding by this law easier to accomplish.

While this requirement may be difficult to meet, if it is met, it reduces many of the variables required to know if the chains are strong enough to maintain control. The following are all good reasons states may have this law:

a. The chains will be short enough so that they are not abraded on the ground. Recall that the chains should be crossed under the tongue. If the tongue can hit the ground, it can grind them on the ground.
b. Chains short enough to keep the tongue off the ground will also not allow significant swing from side to side. Many tow vehicles, such as trucks have a comparatively light rear end. The tongue weight from the trailer adds to the stability of the truck/trailer combination. If the tongue hits the ground, the tongue weight is no longer on the tow vehicle. If the trailer starts to sway from side to side because the chains are long enough to allow it to do so, trailers with a large yaw moment of inertia may cause the vehicle combination to jack knife or overturn.
c. If the chains are short enough to keep the tongue off of the ground, they will not allow the trailer to move significantly toward the tow vehicle protecting it from getting rammed by the trailer. Conversely, if the chains or cables are long and the primary coupling fails and the operator panics and slams on the brakes, the trailer will ram into the back of the tow vehicle.
d. Allowing the tongue to hit the ground can be incredibly violent and dangerous. Imagine the trailer coming off and the tongue hitting a bridge expansion joint, a crack or a pot hole.

In a controlled environment, we tested the effects of primary coupling failure. We designed a coupling that would allow us to test the safety chains when we dropped the trailer from the primary coupling, but would still control the trailer if and when the safety cables failed. Author, Fred Smith, as the driver in the decoupling scenarios noted,

> "There is an incredible difference in the ability to control the trailer when the tongue is cradled above the ground surface, as opposed to when the tongue hits the ground. In the first case the trailer is easy to control, you hardly notice a difference. The second case is much more frightening. Even though I was expecting the decoupling, it was much more difficult to maintain control and come to a safe stop."

At or near freeway speeds, allowing the trailer tongue to fall to the ground is similar to applying a grinding wheel to the parts of the trailer that touch the ground, and the damage is fast and severe. A typical freeway speed of 65 MPH translates to 5,720 FPM (feet per minute). Most grinders operate at surface speeds between 4,000 and 12,500 FPM. As one can imagine this can cause safety chain failure and runaway trailers in addition to property damage, and the need to replace trailer parts. In one test we made, at 50mph, it took <u>less than 1 second</u> for cables being used as safety chains to be ground off, and for the trailer to come completely detached (our specially designed attachment from the tow vehicle to the trailer worked properly and maintained control of the trailer). The ground off cables are shown in the photo below.

SOME GENERALIZED VALUES

In the data below, the measurement of speed is based upon surface feet per minute and not rpm. The actual speed of the abrasive grit on the wheel periphery is set by the length of the path it takes as it revolves about the wheel axis. Larger the wheels have faster surface speed for a given rpm. Simple formulas to convert rpm to the sfpm are published in many books.
Here are some common ranges of speeds reported McGraw Hill Machining and Metalworking Handbook.

TYPE	SPEEDS(sfpm)
Cutoff wheels	9,000-16,000
Cylindrical grinding	5,000-12,000
Disc grinding	4,000-5,500
Internal grinding	4,000-12,000
Portable grinding	6,500-12,500
Snagging	5,000-12,500
Surface grinding	4,000 - 6,500
Tool grinding	5,000-6,000
Weld grinding	9,500-14,200

http://www.abrasiveengineering.com/speeds.htm

Two Safety Chains

The next requirement is that 19 states and SAE J684 require two safety chains. Five states and SAE J684 require them to be crossed and 4 states require the chains to be attached to the side of the tongue. As discussed, this allows the chains to be attached to the sides of the tongue, be crossed under the tongue so the length chain during turning is minimal and also allows the cradling of the tongue.

Only Chains are Specified – No Cables

The next requirement is that 16 states require chains with no allowance for cables. There is actually some reasoning behind this. Most safety cables sold have a set length. While the coiled cable will generally keep them from scraping in the ground under normal use, which is good, they will almost always be too long and let the tongue hit the ground. This causes the inherent problems discussed above. These are different from the straight cables that are made for commercial full trailers (red wagon type) that are made to fit and actually work quite well. Additionally, we have tested a number of cables and found them not to meet the strength the packaging says they will meet. The authors are also aware of other manufacturers of trailer parts that refuse to supply safety cables as the maximum strength of the crimped portion can be difficult to keep consistent.

No More Slack than Necessary

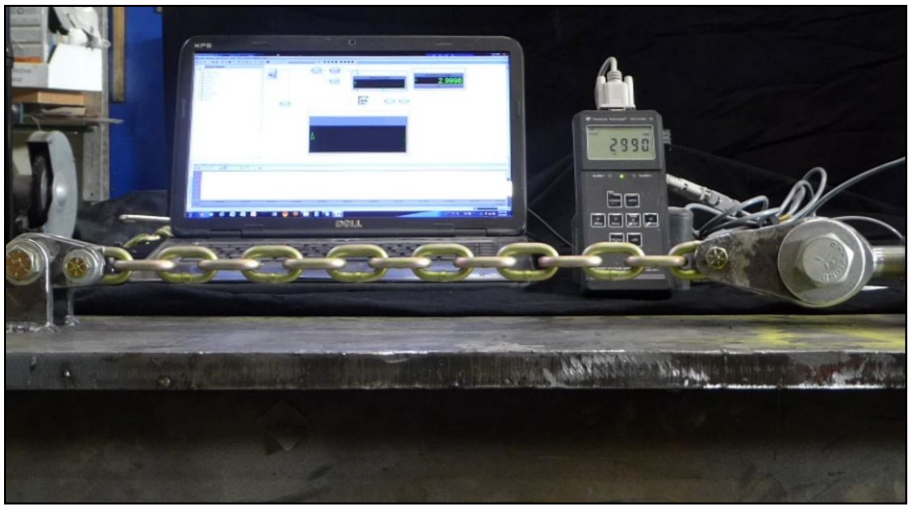
The next requirement is that 13 states and SAE J684 require "no more slack than necessary for proper turning." Four states require the slack in each chain to be approximately equal. When was the last time anyone actually saw a trailer that met this requirement? Hardly ever. This is related to the requirement of the tongue not hitting the ground. When abided by, it will also help keep the chains from being abraded on the ground.

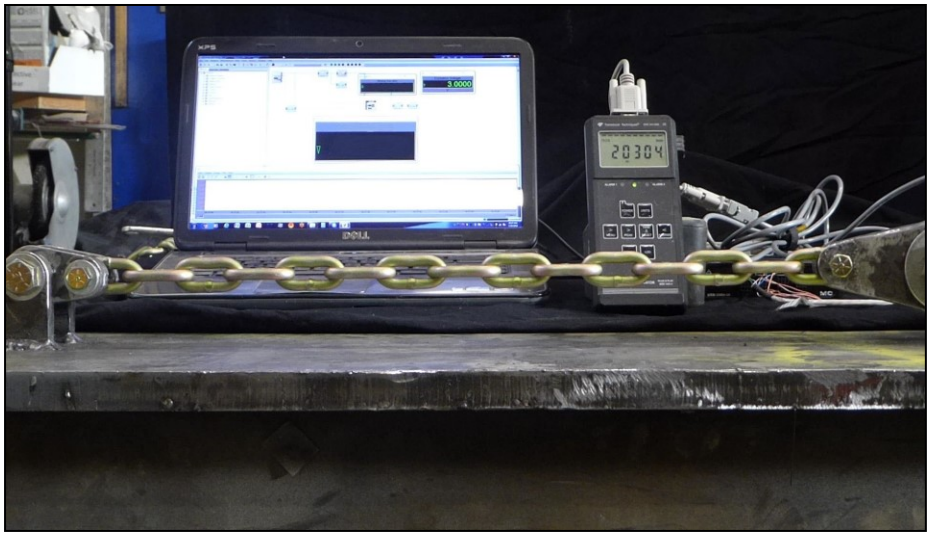
Each Chain Strength at Least Equal to the GVWR of the Trailer

The next requirement is 9 states and SAE J684 that require the chain strength to at least be equal to the weight of the trailer and load (GVWR). This is one of the requirements of SAEJ684. While the exact genesis of this requirement is unknown, there are a couple of likely scenarios where this would be beneficial. For example, on 15 March 2021 there was an accident on an Idaho free way where a truck pulling a recreational vehicle lost control and the truck went over the guardrail over the Malad Gorge. "Only the safety chain between the truck and the camper kept it from falling into the Malad Gorge 80-100 feet below."[13] In this scenario, it is possible that the majority of the weight of the truck was held by a single safety chain.

[13] https://www.kivitv.com/news/heroic-effort-after-crash-on-i-84-leaves-car-hanging-over-bridge-at-malad-gorge

Another possible reason is that if the trailer brakes are applied during a primary decoupling, each chain would be able to take the maximum load applied (coefficient of friction is usually considered to be between 0.7 and 0.8 times the weight of the trailer and load). For two chains sharing the load, this would give a safety factor of well over 2.0. Unless the chains are grossly different in length, the chains will share the load. Our testing has shown that the chain links stretch significantly before failing. A length of chain with 15 links (a little over 1 ft of initial length) can stretch 3-4 inches before failure.





Chains are to be Attached to the Side of the Tongue

Four states and SAE J684 require the chains to be attached to the side of the tongue. The reason behind this was described above. Attaching them to the sides allow them to be crossed and also keeps the attachment points from being ground off as they would be if they were on the bottom of the trailer.

Positive Safety Connections

Four states require the connection to be positive. One might consider positive to mean that it cannot be undone by any normal driving of the trailer and that the connections are as strong as the chain. SAE J684 actually requires the attachments to meet the same strength requirements as the chain.[14] In most cases, the authors believe that "positive Safety Connections would mean that the hooks attaching the chain to the tow vehicle are gated so they cannot come off under any acceleration or force that may come by driving over bumps, through dips and the like. The photo below shows some typical safety chain hooks that the authors do not believe would meet this law.

[14] SAE J684, 7.5.1.

Miscellaneous Laws

Most of the remainder of the state laws are similar to those already discussed. The requirement that they "Must meet DOT or SAE Standards" would include most all of what has been already discussed. The requirement that "Chain strength sufficient to haul the loaded trailer" is similar to the chains being equal in strength to the GVWR of the trailer.

The requirement which states "Do not use the ball/coupling fasteners to attach the chain" makes sense as one would not want the secondary coupling to fail along with the primary coupling.

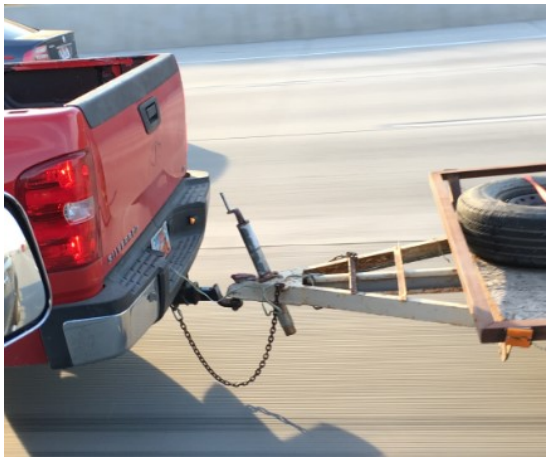
The requirement that "The minimum chain or cable to be ¼ inch" is similar to the strength requirement.

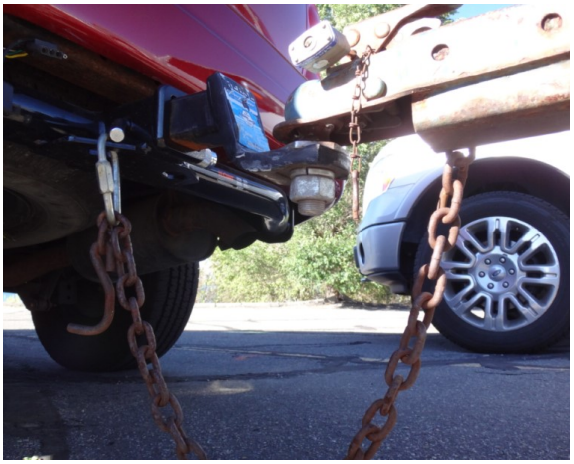
The requirement to "Attach equal distance on opposite sides of the centerline" allows the chains to be crossed as discussed above and be easier to see that they are the same length.

Lastly, the requirement that "chains are not to be welded to the trailer chassis" is important as our testing shows a decrease in strength of almost 50% when some chains are welded.

VIII. What's Wrong with These Trailer Chain Attachments?

While attaching safety chains should be simple and straight forward, it is very rarely done correctly as shown in the following pictures of trailer attachments taken on the way to or at Deer Creek Reservoir in Utah (further examples are contained in Exhibit 2). Now that you have an idea of what the trailer chain standards and state laws require, look at the following photos and see if you can identify what is wrong with the chains. It's actually quite scary how many safety chains are improperly attached.





Frankly, it is terrifying knowing that we are on the road at the same time that these types of trailers are being towed. In all of the above scenarios, if the primary coupling fails (estimated at one failure every 26 minutes) the trailer tongue will undoubtedly fall to the road surface and many of the above attachment will be ground off in a matter of seconds making the secondary connection totally ineffective.

IX. What Can Be Done?

What can be done to ensure that trailer safety chains are installed, attached, and used properly to reduce or eliminate the number of runaway trailers and to improve the safety of our roads? There are at least three groups that bear responsibility in keeping all of us safe: users, trailer manufacturers, and law enforcement.

- Users: People who tow trailers for work or pleasure bear responsibility for knowing the laws, regulations and best practices for attaching their trailer to their tow vehicle. They also have a responsibility to ensure that best practices are implemented and followed. There is no room for incompetence or negligence when lives are on the line. Even with vigilance, there are bound to be instances where the primary coupling fails.

- Manufacturers: Manufacturers arguably should have the best understanding of the laws and standards regarding the proper installation, attachment, and use of safety chains. The difficulty for manufacturers, as previously discussed, lies in the fact that proper attachment depends on both the trailer being towed as well as the tow vehicle. Trailer manufacturers often provide safety chains that are easy to use with their trailers, however, chains that are long enough to accommodate attachment to the tallest trucks or those where the ball extends way out beyond the chain attachment area, will allow the trailer tongue to hit the ground when attached to a vehicle with a lower chain connection (e.g. a Honda Pilot). And vice versa, chains that are appropriately sized to a smaller vehicle will not reach to the connection points on a vehicle using a drop hitch. In the past manufacturers have apparently expected the end user to modify the chains to the proper length when attaching the trailer to their vehicle. This can be difficult for some, particularly when the trailer will not be towed by a dedicated vehicle (rentals, construction

trailers, etc.). It would be much better if manufacturers provided end users with a safety chain system that allowed the end user to simply and easily adjust the length of the safety chain to properly fit any vehicle. It would also be helpful if how to make that adjustment was easy to ascertain, so it didn't require someone having to know how to cut, twist or otherwise modify the safety chain. It would also be helpful if how to make the adjustment was self evident so that most anyone looking at it would not only know what it was for but how to make the adjustment.

- Law enforcement: While it is no secret that law enforcement officers typically do a fantastic job at keeping the piece and preventing accidents, for some reasons the proper use of trailers and safety chains has gone largely unregulated. Given the trailer and safety chain attachments shown above, it stands to reason that law enforcement could provide invaluable support for proper installation, attachment and use of safety chains.

X. How the Safety Chains are attached to the trailer

Federal law requires that two safety chains should be used. The SAE J684 Standard and suggests that trailer chains should be permanently attached to the trailer tongue, one on each side. Often, trailer safety chains are attached to the bottom of the tongue, or to a guard welded to the bottom of the tongue. Attaching the chains on the side of the tongue is the best option, as attaching them to the bottom of the tongue or a guard increases the likely hood that that they will be ground off in the event of a primary coupling failure. As shown below, the guard that the trailer chains are attached to has been ground down significantly, likely due to a low speed decoupling. Once it is ground all the way through, testing shows that it will fold down exposing the safety chain connecting bolts to the road surface.

The standard also recommends that the two safety chains are permanently fastened or anchored to the trailer tongue. Welding safety chains is generally not recommended as the heat can weaken the chain material reducing the strength of the chain. Our testing shows most ways of connecting a grade 70 chains (bolting, welding, and d-links) reduce the strength by nearly 50%. The SAE standard clearly states that "Any operation performed on a safety chain subsequent to its manufacture shall not reduce the strength below the requirements" shown in the table in the Standards section above.

The safety chains should also be connected as far forward on the trailer as is reasonably possible. The further back the chains are connected, the more likely the tongue will contact the ground in the event of a primary coupling failure. Also, the further back the safety chains are connected, the more likely the trailer is to run into the back of the tow vehicle when slowing down. In the event a folding tongue is implemented on the trailer tongue, there should be an auxiliary connection between the swing tongue and the frame of the trailer. In many instances manufacturers attach the safety chains rearward of the swing tongue. If the chains do not have another attachment point closer to the coupler end, there is no way to keep the tongue from hitting the ground.

The use of safety cables as safety chains, while not expressly prohibited by the standard, requires close examination. More often than not, safety cables will also allow the trailer tongue to hit the ground in the event of a primary coupling failure. Safety cables have become popular as they can be manufactured in a coiled state, which keeps them up off of the ground when attached to the tow vehicle. They are made with plenty of length to be able to quickly attach to any tow vehicle. The problem is, though, that the additional slack in most cases will allow the trailer tongue to fall straight to the ground in the event of a primary decoupling.

XI. Proper Safety Chain Connection (How to attach to the tow vehicle)

Once the trailer chains are properly installed on the trailer, they must also be properly attached to the tow vehicle if they are to serve their purpose. SAE J684 and a number of state laws require that the safety chains be crossed under the tongue. They should be crossed under the tongue of the trailer so that the chains cradle the tongue in the event of primary coupling failure. SAE J684 and a number of state laws also require that the length of chain used shall be no more than necessary to permit proper turning of the vehicle.

There are a number of common ways to adjust chains to make them the proper length for a vehicle including cutting chains to the right length, doubling back on the chain, and twisting the safety chains. Unfortunately, all of them have significant limitations.

One method of adjusting safety chains to the proper length is to remove them, cut them to length, and re-attach them. This is an effective way of achieving the proper length, but has several drawbacks. First, this is difficult and time consuming process, and thus rarely happens. Furthermore, cutting a safety chain is not a reversible process. Once the chain is cut, it can never be used in a situation where a longer chain would be desirable. For example, if the trailer is going to be pulled by a different tow vehicle.

Another way of adjusting the length of a trailer safety chain is to feed the end of the chain through the vehicle chain connection, double it back on itself and make a connection. This method also has several problems. First, many safety chains are equipped with hooks that are too large to fit entirely through the vehicle chain connection loop as shown below. Such chains are not meant to be and actually cannot be doubled back without removing the hook. A second difficulty lies in how the chain is secured back to itself. Historically this has been done by fitting a bolt through the end of the chain and a more central link of the chain, and securing the bolt with a nut. Another way this has been done is with a hook

that is small enough to fit through the chain attachment on the tow vehicle receiver. The problem with using a bolt and nut is that it is well known that nuts come loose particularly under vibrations, like driving down a road. This is explained in the following YouTube video: https://www.youtube.com/watch?v=IKwWu2w1gGk. Hooks that are small enough to fit through the receiver chain attachment loops often lack the strength required, and thus are rarely used. For these reasons, adjusting the length of a chain by doubling it back on itself has fallen out of favor, and rightly so.

Twisting chains is another commonly recommended solution to chains that are too long. However, this also has significant drawbacks. First, most chain manufacturers say not to twist the chains because the load ratings only apply to longitudinal force. Again the SAE684 standard states that nothing should be done to the chain that reduces its strength. Further, testing we have done shows that twisting safety chains can reduce their strength by as much as 75%. Some chains are better than others in this type of loading, but all that we have tested reduced in strength by at least 25%. To put that into perspective, some chains rated to 10,000 lbs, would only be able to hold 2,500 lbs. Further, a small amount of force can cause the twisted chain to lengthen significantly. This can also lead to the tongue contacting the road. Twisting trailer chains is not recommended as a safe solution to trailer chains with excess length.

XII. What Trailer Manufacturers Can Do to Limit Their Liability

Whenever there is a serious accident involving a trailer, it is not uncommon for a trailer manufacturer to get pulled into the lawsuit with the plaintiff's attorney claiming that the trailer was defective. A product defect is anything that renders the product not reasonably safe. Product defects generally fall into two categories, either a manufacturing defect or a design defect.

Manufacturing defects become part of the product when it is made. They are most often caused by poor quality materials, wrong materials, departure from the intended design from carelessness in following the design or simply shoddy workmanship.

Design defects, on the other hand, as the name implies are problems with the products design that makes it dangerous. In examining whether your trailer has a design defect, a hazard analysis should be done. Since in this paper we are talking about safety chains, one would examine the hazards involved with safety chains. Many of the hazards involved with safety chains revolve around whether they do their job of keeping the trailer attached to the tow vehicle in the event of the primary coupling coming undone allowing the combination to come safely to a stop. So what could go wrong? The following is a list of some of the things one might consider:

a. The chains or their attachment might be too weak and they break allowing the trailer to become totally detached.
b. The chains are too long and they allow the trailer to hit the ground, grinding the chains off allowing the trailer to become totally detached
c. The chains are too long and they allow the trailer to hit the ground and the trailer sways from side to side jack knifing or over turning the vehicle.
d. The chains are too long and their attachment hits the ground first before the tongue and gets ground off causing the trailer to become totally detached.
e. The chains are too long and drag on the ground such that the links are compromised. If the trailer comes off it may become totally detached.
f. If the chains are too long the tongue can hit the ground and get stopped on expansion joints, cracks, potholes and the like.
g. Chains that are too long and drag may create sparks, starting a fire.
h. The chains are too long and allow the trailer to ram the tow vehicle.
i. The chains are replaced with chains that are weaker that what the manufacturer originally specified and no one can tell.
j. The chain attachments have not been tested and are weaker than required.
k. The chains are too short and will not attach to the tow vehicle. If they cannot be attached they cannot be effective.
l. The chains are too short and bind when a turn is being made. The chains may break if the bind becomes severe which would allow the trailer to become totally detached from the tow vehicle.
m. Chains become corroded and lose their strength.

Once all the hazards have been identified, the severity of harm from the hazard is determined. It is beyond the scope of this paper to go through that analysis. The probability that the hazard will occur is then determined. Again, this is beyond the scope of this paper. A standard matrix such as found in ANSI B11.TR3, ANSI Z590.3 or MIL-STD-882D is used to determine the risk. If the risk is determined to be high enough it should be reduced.

The safety hierarchy or hazard control hierarchy is a well accepted priority scheme for dealing with product hazards. This hierarchy is generally couched as design it out, guard and warn. In this order of preference, alternative designs that eliminate or reduce the hazard are examined first. If such is not economically or technologically feasible, then guarding would be the next approach. Guarding usually is considered as a way to prevent contact between the hazard and the user. Guarding also is sometimes not feasible. The third line of defense is warnings. Warnings are to provide information on how to use the product safely.

In examining the hazards, trailer manufacturers should consider the following:

a. Assure that chains and their attachments are as strong as the GVWR of the trailer.
b. Chains should be designed to be attached properly and be the proper length such that the tongue will not hit the ground if the primary coupling becomes decoupled.
c. Assure either through testing or certification attachments meet the required strength requirements.
d. Eliminate using curly cables as they have been shown to be unreliable as to strength and the way they are generally used on automotive type trailer couplings do not allow the tongue to be kept from hitting the ground.
e. Consider using only class 43 or 70 chain that meets the National Association of Chain Manufacturers (NACM) specifications. In 5/16” and 3/8” chain in grade 43 and 70 must be embossed at intervals of no greater than 1 ft. For these sizes Grade 30 is only embossed every 3 ft. One might consider only using chain and sizes where the type of chain would always be identifiable. Some manufacturers emboss ¼” grade 30 chains also.
f. Providing a warning regarding the type of chain to be used for safety chains on their trailers and what the minimum thickness of a link is before the chain must be replaced. (See the NACM specification, Table XIV)
g. Providing a convenient way to store the chain off of the ground when the trailer is not being used to better resist corrosion.
h. Use only hooks with gates or other just as effective method for attaching the chains and keeping them attached to the tow vehicle.
i. Follow the chain manufacturer’s instructions not to twist chains. That way there is no dispute. Recall that our testing showed up to a 75% decrease in strength for twisted chain compared to non-twisted.
j. Provide proper instruction on how to attach and test the safety chains to assure that they will keep the tongue off the ground and will not bind when turning. This is particularly important as very few people attach them correctly.

XIII. Solving the Problem

Fortunately there is a simple and safe solution that allows trailer manufacturers to install chains on their trailers that allow the end user to conform to **all of the laws and standards** regarding safety chains.[15] The Link Lock™ system uses a patent pending chain adjustment method to allow you to quickly and easily adjust the length of your trailer chains. The Link Lock™ system uses a sleeve that is permanently attached to the sides of the trailer tongue. The chain slides through the sleeve with ease and the sleeve's shape maintains a specific alignment of the chain links. The sleeve aligns the chain to allow a pin to be inserted through holes in the sleeve and through one link in the chain, locking the chain in the sleeve. This makes adjusting the length of your chains, whether longer or shorter simple, fast, and efficient!

When you are hooking up the trailer all you need to do is pull the pin out of the sleeve, adjust the slack in the chain to fit the towing vehicle and hitch, then reinsert the pin to lock the chain in place. An R-pin on a retention cable is inserted in a hole in the end of the pin to assure that it will not come out, no matter what you might drive over. Repeat the process for the other chain and you are done! The Link Lock™ is designed to place the chain in the proper position so it is easy to insert the pin. If needed, any of the excess chain hanging out the back of the sleeve can be hooked over the pin to keep it from dangling too far below the tongue. The pin is permanently attached to the chain so you can never lose it and it meets the requirement of the chain being permanently attached to the trailer. Another advantage of the pin being attached to the chain is it prevents the chain from completely pulling through the sleeve should someone forget to put the pin back in the sleeve.

Alpine Engineering & Design, Inc. has tested the Link Lock™ system and certified that it meets the strength requirements for Class 4 trailers as stated in SAE J684. That means that the Link Lock™ system can be used on any class of trailer covered by the SAE J684 standard. We have failed grade 70 chain at over 20,000 pounds without failing the Link Lock™ chain attachment.

[15] The hitch on some vehicles is so close to the ground that it is virtually impossible to keep the tongue off the ground.

Link Lock™ offers a free audit of current safety chain systems for manufacturers. The analysis provides strengths and weaknesses in connection with relevant laws and standards, and if shortcomings are found, recommendations for properly installing the Link Lock™ system on their trailers are provided. Call Link Lock™, LLC today: 801-772-0266 and have the ease and security of safety chains done right.

Exhibit 1: Crashes Involving Trailers

MOTOR VEHICLE TRAFFIC CRASHES INVOLVING
A PASSENGER VEHICLE WITH A TRAILING UNIT, BY YEAR AND CRASH SEVERITY
FATALITY ANALYSIS REPORTING SYSTEM (FARS) 1975-2014 FINAL & 2015 ARF
GENERAL ESTIMATES SYSTEM (GES) 1988-2015

Year	Crash Severity						Total	
	Fatal Crash		Injury Crash		Property Damage Only Crash			
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1975	355	100.0%	NA	-	NA	-	355	100.0%
1976	330	100.0%	NA		NA		330	100.0%
1977	326	100.0%	NA	-	NA	-	326	100.0%
1978	362	100.0%	NA	-	NA	-	362	100.0%
1979	314	100.0%	NA	-	NA	-	314	100.0%
1980	356	100.0%	NA	-	NA	-	356	100.0%
1981	352	100.0%	NA	-	NA	-	352	100.0%
1982	338	100.0%	NA	-	NA	-	338	100.0%
1983	345	100.0%	NA	-	NA	-	345	100.0%
1984	376	100.0%	NA	-	NA	-	376	100.0%
1985	367	100.0%	NA	-	NA	-	367	100.0%
1986	403	100.0%	NA	-	NA	-	403	100.0%
1987	434	100.0%	NA	-	NA	-	434	100.0%
1988	395	0.8%	13,309	26.5%	36,453	72.7%	50,157	100.0%
1989	448	1.1%	10,363	25.8%	29,329	73.1%	40,139	100.0%
1990	412	0.9%	9,592	22.0%	33,563	77.0%	43,567	100.0%
1991	404	0.9%	9,488	21.2%	34,835	77.9%	44,727	100.0%
1992	422	1.0%	11,557	27.4%	30,269	71.6%	42,249	100.0%
1993	395	1.0%	8,853	22.3%	30,461	76.7%	39,709	100.0%
1994	381	0.8%	12,193	26.1%	34,081	73.0%	46,655	100.0%
1995	387	0.8%	11,835	24.8%	35,593	74.4%	47,815	100.0%
1996	396	0.7%	15,812	26.0%	44,675	73.4%	60,883	100.0%
1997	398	0.6%	15,530	25.1%	45,922	74.2%	61,850	100.0%
1998	394	0.8%	15,094	31.8%	31,934	67.3%	47,422	100.0%
1999	405	0.6%	21,508	32.6%	43,991	66.8%	65,904	100.0%
2000	353	0.6%	15,874	28.5%	39,512	70.9%	55,739	100.0%
2001	329	0.6%	14,316	26.0%	40,445	73.4%	55,091	100.0%
2002	313	0.6%	14,022	27.3%	36,968	72.1%	51,304	100.0%
2003	365	0.7%	14,484	26.4%	40,080	73.0%	54,929	100.0%
2004	362	0.6%	17,467	27.1%	46,737	72.4%	64,566	100.0%
2005	428	0.7%	16,482	25.6%	47,368	73.7%	64,278	100.0%
2006	363	0.7%	11,746	21.5%	42,520	77.8%	54,630	100.0%
2007	387	0.7%	12,704	23.8%	40,320	75.5%	53,411	100.0%
2008	339	0.6%	11,898	19.4%	49,107	80.1%	61,345	100.0%
2009	323	0.6%	12,736	22.5%	43,621	77.0%	56,680	100.0%
2010	338	0.6%	13,879	24.8%	41,747	74.6%	55,964	100.0%
2011	305	0.8%	9,910	24.4%	30,403	74.9%	40,618	100.0%
2012	323	0.6%	11,262	21.7%	40,241	77.6%	51,826	100.0%
2013	310	0.6%	10,496	21.5%	37,971	77.8%	48,776	100.0%
2014	332	0.7%	14,555	29.0%	35,308	70.3%	50,195	100.0%
2015	387	0.7%	11,182	21.4%	40,751	77.9%	52,320	100.0%
1975-2015	15,052	1.0%	368,149	25.1%	1,084,207	73.9%	1,467,408	100.0%

Passenger vehicle: passenger cars and light trucks (SUVs, pickup trucks, vans, and other light trucks).

NOTE: The above 'Injury' and 'Property Damage Only' crash numbers are not actual counts, but estimates of the actual counts. The estimates are calculated from data obtained from a nationally representative sample of crashes collected through NHTSA's General Estimates System (GES). Estimates should be rounded to the nearest 1,000.

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Exhibit 2: Other Examples of Improperly Attached Safety Chains


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