WHEN — Q2 2015
Federal Safety Standards for Heavy Trucks - Part 4

Update #2350

Attention: Dayton Parts' Distributors and Business Partners.

The Q2 2015 issue of **WHEN** (**WH**eel **E**nd **N**ews)

In the last edition of WHEN we looked at the evolution of the s-cam brake which has been the dominant foundation brake for heavy trucks since its inception in the 1940's. The interstate highway system, along with increases in engine horsepower, have enabled heavy trucks to travel at speeds much faster than when the s-cam brake was invented. This along with the recent 30% reduction in stopping distance for class 8 trucks has presented quite a challenge for our old reliable workhorse. Advancements in electronic technology (in its infancy in the 1940's) have helped by giving us ABS systems that control the air supply pressure at a level of precision we only dreamed of when the original FMVSS-121 standard was implemented in 1975. With all that being said, can the s-cam brake still safely control all the *"horsepower"* out there amongst the ever increasing light vehicle traffic? To answer that question let's first take a look at the demands that are being placed on heavy truck air brakes.

The Original Horsepower

The power to go and the power to stop

In 1955 the average gas engine for heavy trucks produced around 150bhp (brake horsepower). Today 400bhp is common and 500+ is not that unusual. Obviously with three times the horsepower it's going to be much easier to get things rolling faster in less time. Question is can you stop it? Better yet, can you make a controlled stop, especially if it's a *"panic"* one?

In Part 2 of this series, we looked at the railroad industry and how locomotive horsepower was increasing so more carriages (weight) could be pulled faster (speed) to arrive at their destination sooner.

However the brake systems remained relatively unchanged to the point a train needed half a mile to make a stop. That's almost nine football fields end to end. This situation prompted Mr. Westinghouse to design an air brake system which has remained fundamentally the same to this day.

In the business world there is this constantly repeating cycle of more, faster, sooner that competition continually drives. Could the heavy truck industry be at a point where weight and especially speed have outgrown the existing foundation brake design? To get an idea of the correlation between engine horsepower and the brake force needed to control it let's take a look at a couple of illustrations.

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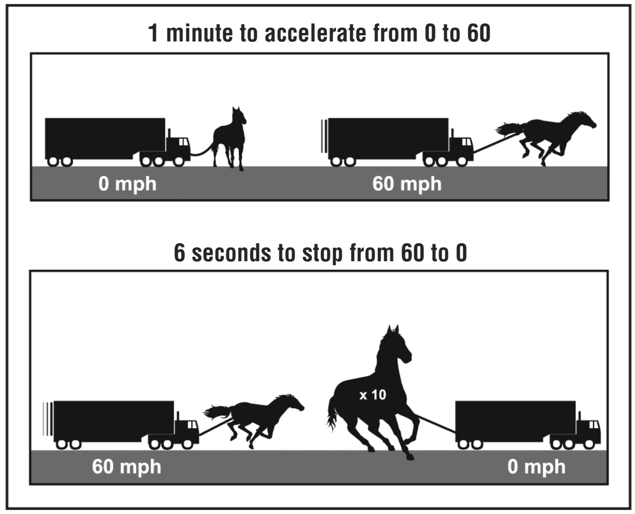
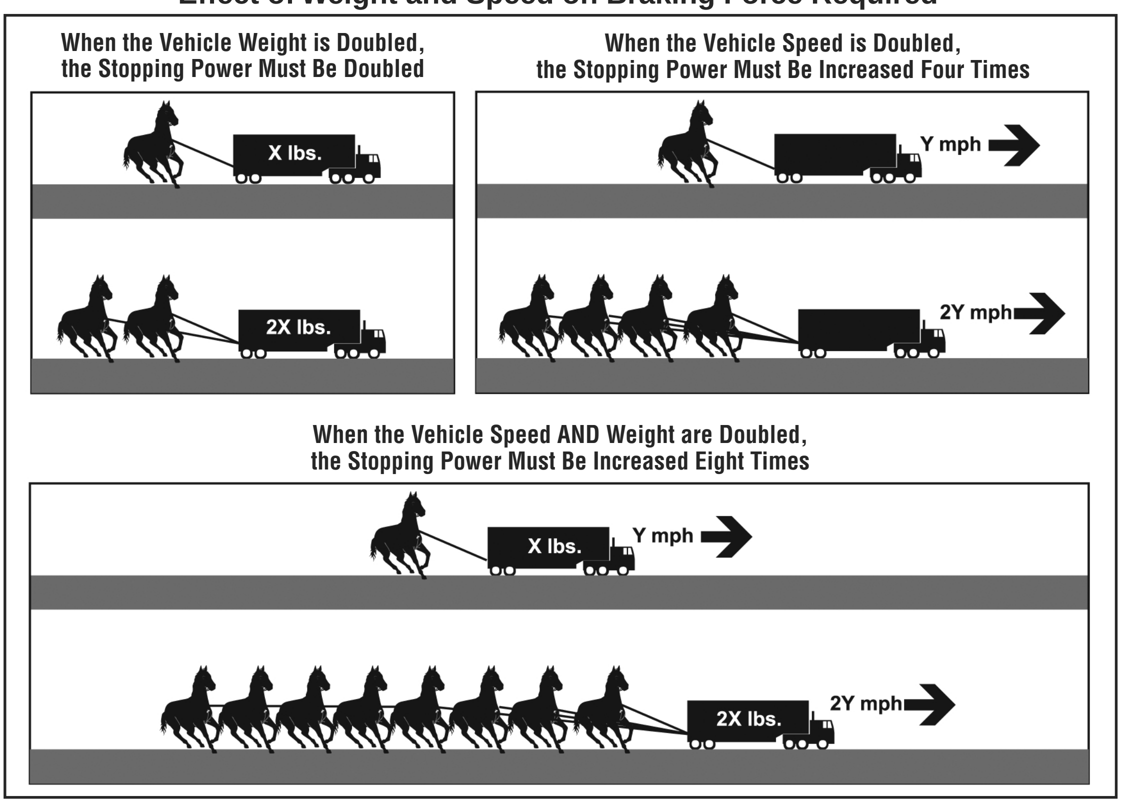
We have a truck that takes a minute to go from 0 to 60mph. On highways today 60mph is very common place so let's break that down. At 60mph this vehicle is covering a mile a minute (60mph ÷ 60 minutes in an hour = 1 mile/minute). Now let's break that down just a little bit further. What is a mile a minute in feet per second? A mile is 5,280ft and a minute is 60 seconds so 5,280ft ÷ 60 sec = 88ft/sec. Think about that for ***a second*** and you just went 88ft further down the road. On a typical highway today what would we normally find 88ft in front of us? Traffic, wouldn't we. How much? Good question. When I took driver's ed back in the mid 70's we were told to leave one car length for every 10mph of speed. The average light truck or four door sedan today is about 17ft long so 60mph/10 would be 6 car lengths or 17ft x 6 = 102ft. That being said, it seems reasonable there would be at least one light vehicle for every 88ft in front of us. Keep that in mind throughout the remainder of this article.



Forces Involved in Braking

Now, how long does it take to stop? Remember it took 60 seconds for our truck to accelerate from 0 to 60mph. What do you think would happen if our truck took 60 seconds to stop? That would ***not*** be good. Fact is we're going to want our truck to stop in ***6 seconds or less***. To do that the brake system will have to take the energy the drive train has turned into forward motion and change it into heat as it stops the vehicle in $1/10^{th}$ the time. This means the brake system is readily called upon to do 10 times the work that the engine does (60 seconds to accelerate ÷ 6 seconds to stop = 10). Granted we have ten brake assemblies for one engine on a regular tandem tractor/trailer combo (note the ratio is 10:1) which really drives home the point that ***every*** brake assembly on the vehicle needs to be functioning properly, doesn't it. As we can see generating power and being able to control it are two totally different things. Now let's take this a little further.

Effect of Weight and Speed on Braking Force Required



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The impact of weight and speed

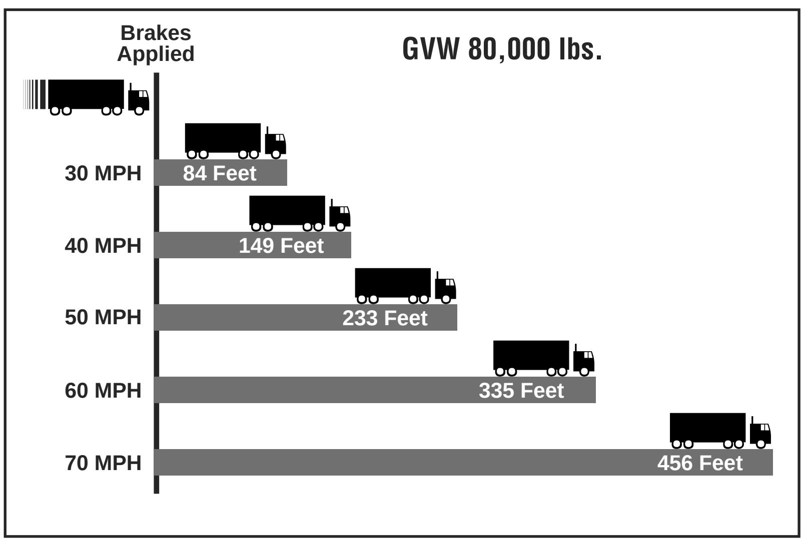
From the illustration **“Effect of Weight and Speed on Braking Force Required”** *(bottom of page 2)*

Weight - *Upper left hand box* - When the weight is doubled then the amount of brake force must also be doubled ***if*** we’re going to stop in the same distance.

Speed – *Upper right hand box* – When the speed is doubled then the amount of brake force must increase by a factor of 4 ***if*** we’re going to stop in the same distance.

Weight & Speed – *Lower box* - When the weight and speed are both doubled, then the amount of brake force must increase by a factor of 8 (weight factor of 2 x speed factor of 4 = 8) ***if*** we’re going to stop in the same distance.

So why is that? Why does weight have an impact ratio of 1:1 while speed is 2:4 or the rate of increase squared? Because weight is a constant so 50lbs moving at 10mph is still 50lbs at 20mph or 30mph, etc. Acceleration (speed) on the other hand increases exponentially and consequentially so does deceleration. It’s important to remember that even at peak performance there is a limit to how much brake force a brake system can generate. There will come a point where the increase in weight and/or speed will exceed the brake system’s ability to stop the vehicle within a safe distance no matter how hard you *“stand on”* the treadle. That’s a limit we don’t want to go looking for let alone find, agree? First let’s take a look at how speed affects our stopping distance while the weight stays the same.

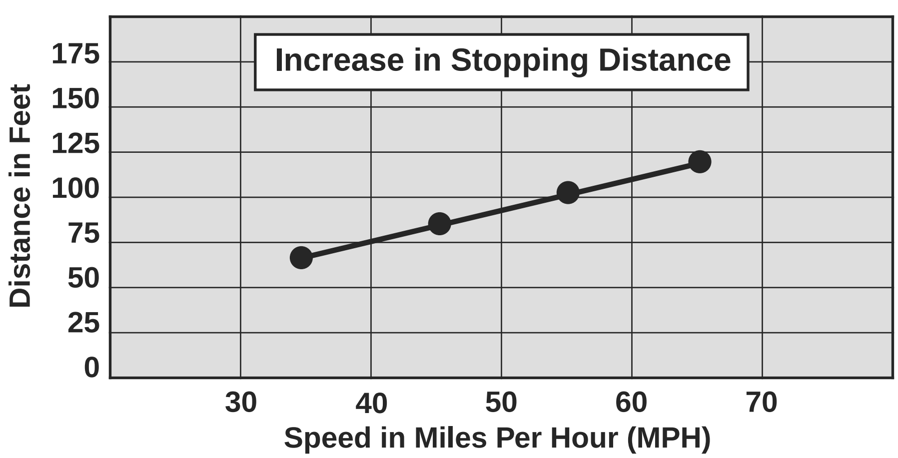


Effect of Speed on Stopping Distances

Notice how the stopping distance increases on a curve as the speed increases –

30 – 40mph – 65ft increase
40 – 50mph – 84ft increase
50 – 60mph – 102ft increase
60 – 70mph – 121ft increase

Here are the increases in stopping distance plotted on a graph.



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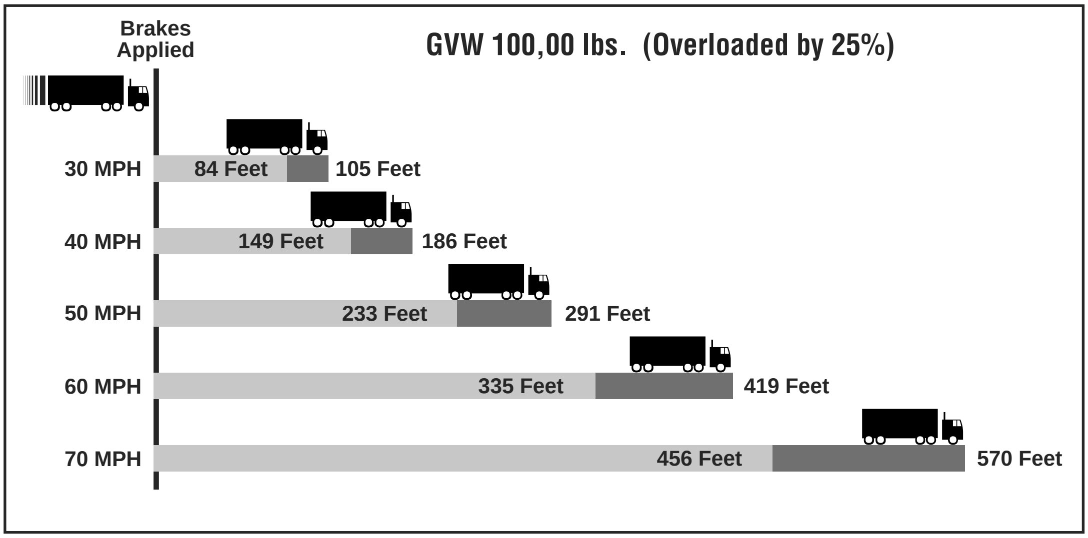
Now what if our truck is overloaded 25% grossing out at 100,000lbs ((100,000/80,000) – 1 = .25 or 25%). How much does that impact our stopping distances? Remember weight is a constant so the impact will be 1:1 which means the stopping distances will also increase 25% across the board.



Effect of Speed on Stopping Distances — Vehicle Overloaded by 25%

Notice the stopping distance at 60mph has increased by 84ft to 419ft, however, the stopping distance at 50mph is 291ft. That is 44ft less than the original 335ft at 60mph before the weight was increased. Does that mean if our truck is overloaded 25% then all we have to do is back down on the speed say 15% and we're good? Let's take a closer look at that *"theory"*. Remember if the weight has increased 25% then the brake system is working 25% harder thereby generating 25% more heat. In the course of our day we have some stops where the drum temperature was hitting say 475˚ ***before*** the weight was increased, which is a normal hot stop (a hot stop is considered between 400° and 650°). Tack on another 25% and we're at 594˚ (475° x 25% = 119° and 475° + 119° = 594°). This is not implausible considering the gross weight of our truck especially at the end of a downhill grade. At 650° the resin that holds the friction material together will begin to boil and evaporate changing the top edges of the brake block to a gray ash color as it flakes apart. We're starting to reach the limit of the brake system aren't we? What if our truck is running some of those awesome *"value"* drums with 7lbs less weight to absorb and dissipate the additional heat being generated? Do you think we'll see any *"drum expansion"* or *"heat checking"*? I think that's a fair assumption. A good case in point why *"value"* drums need not apply. If fact, by the time we get stopped those *"value"* drums won't remember what round looks like!

So, did the brake system have another 25% of brake force capacity available to handle the increased work load? It doesn't appear so, does it? Many systems are purposefully built stronger than needed for normal usage to allow for emergency situations, unexpected loads, misuse, and wear. In mechanical engineering this is known as the **FoS** or **"Factor of Safety"** as expressed in the formula below –

$$s_w = S_m / f_s$$

S_m = Allowable working unit stress

s_w = Working stress (Allowable stress)

f_s = Factor of Safety

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When the components are subjected to repeated shock loading (like a brake system) then the Factor of Safety (f_s) should not be less than 10. So let's give the working stress (s_w) a value of 1 and see what we get.

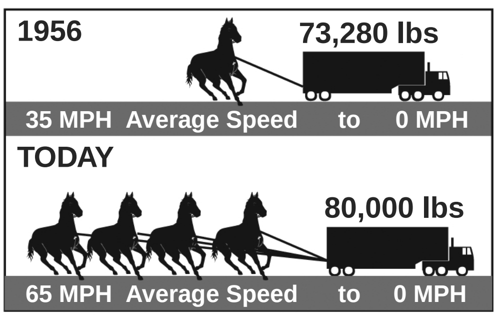
1 = 1/10 = .10 or 10%

That 10% of *"over engineering"* is to provide a margin of safety, not extra capacity. That's why it's never a good idea to exceed the GVW (gross vehicle weight) of any vehicle. Now let's take a look at how all of this has changed the demands placed on heavy truck brakes.

In the Real World

Now let's apply all of this to real world circumstances. In 1956 when the Federal Highway Aid Act was passed it set the maximum gross weight allowed on highways at 73,280 lbs. This act makes no mention of any stopping distance requirements of any kind. On the drawing board were 41,000 miles of interstate highways that would be built over time as money was allocated. The only way to travel at that time was on two lane roads at an average speed of 35mph. So let's do a little math here.

We've gone from 73,280lbs to 80,000lbs which is an increase of 9.1% ((80,000/73,280) – 1 = .091 or 9.1%). That's not a lot. Speed on the other hand has increased from an average of 35mph to 65mph which is a little trickier since it's the rate of increase squared. So let's see, 65 ÷ 35 = 1.86 and 1.86 x 1.86 = 3.46 and tack on 9.1% for the weight increase = 3.77. In other words the s-cam brake system today is working almost 4 times harder than it did in 1956 just from the increase in weight and speed.



Effect of Weight and Speed on Brake Force Required to Stop a Vehicle, 1956 -vs- Today

This does ***not*** take into account the recent 30% reduction in stopping distance for class 8 trucks. Are you beginning to see the real reason for the whole 4707 brake assembly with thicker lining and why all those outrageous claims of increased mileage never came close to materializing? I think so. Now let's look at the overall design of the s-cam brake and see if it's still up to the task.

Is the S-Cam Brake still up to the task?

If everything in the s-cam foundation brake is in good shape and the auto slack is working properly, then the brake shoes should be sitting somewhere between 0.015" – 0.020" from the drum at the center of the shoe in the released position. Obviously the cam head doesn't have to rotate too far for the brake shoes to contact the drum (again if everything in the foundation brake is in good shape). A standard 3030 air chamber has a pushrod stroke of 2.5" and by law we are allowed to use 80% of that or 2.0", no more. So we just did a brake job on a vehicle and everything is up to snuff, right? How much pushrod stroke should it take then to make a brake application? I get asked that question quite often and the answer is *"The less the better"*. Huh? I know, it sounds like a politician dodging a question doesn't it. The 2.0" stroke limit on a standard 3030 air chamber is just that, a limit. Fact is the less pushrod stroke used initially means the more there is available to compensate for wear in the system while the brake assembly is in service. I also get asked this question regularly, "After a brake job, shouldn't all four wheels use about the same amount of stroke, say within +/- 1/8" ?" Actually it's hard to put an exact number to it because of all the variables involved like machining tolerances, variances in components and wear. Remember the s-cam brake is a brake force multiplier made from three levers linked together with components and wear points. Let's see how many there are.

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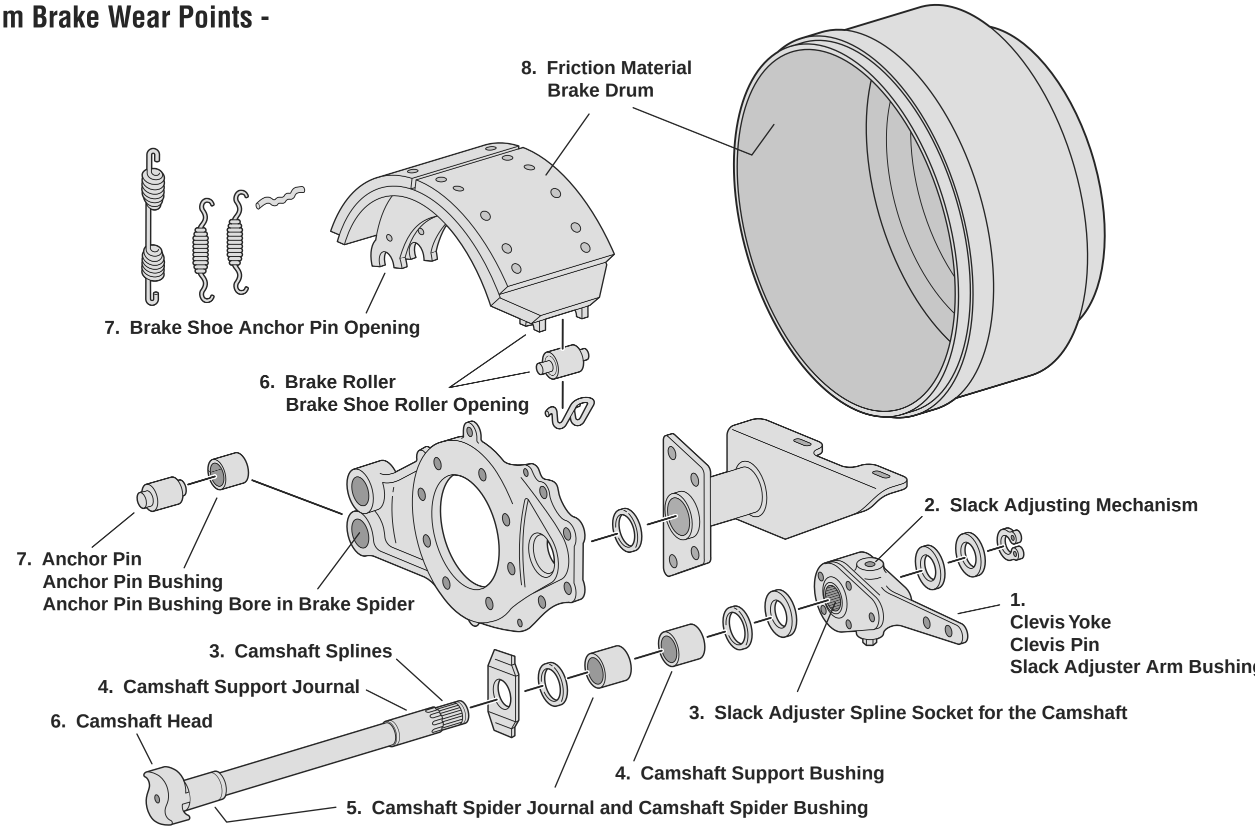
S-Cam Brake Wear Points -



Wear Points and Their Components

1. Clevis yoke, clevis pin and slack arm bushing
2. Slack adjusting mechanism
3. Slack spline socket for the camshaft and camshaft splines
4. Camshaft support journal and camshaft support bushing
5. Camshaft spider journal and camshaft spider bushing
6. Cam head, brake roller and brake shoe roller opening
7. Brake shoe anchor pin opening, anchor pin, anchor pin bushing and anchor pin bushing bore in the brake spider
8. Friction material and brake drum

So we have 19 components at 8 different wear points inherent in the design. Granted, the machining tolerances on all of these components are tight when the parts are new, however, over time the accumulative effect from just general wear can add up with the amount of *"linkage"* involved. Naturally as the friction material and brake drum wear the auto slack should do its job and rotate the cam head to keep the brake shoes at the proper clearance to the brake drum. However, all of those moving parts wearing on each other can lead to brake assemblies becoming non-effective while in service if not maintained properly. Let's go back to our stopping distance charts and see what happens when some of the brake assemblies are out of service (OOS).

All "Brakes" on deck

As stated earlier the brake system on our truck works 10 times harder than the power train does. Why is that? For one thing there's no *"acceleration limit"* for heavy trucks. If one truck accelerates from 0 to 60mph in a minute and another truck takes two minutes (that would be my truck) what impact does that have on safety. None really, does it. However, how many feet it takes to stop our truck will have a huge impact on safety. Remember, at 60mph there's one light vehicle every second down the road in front of us. That's why as stated earlier, a regular tandem tractor/trailer combo will have one engine compared to ten brake assemblies and all of them need to be functioning properly.

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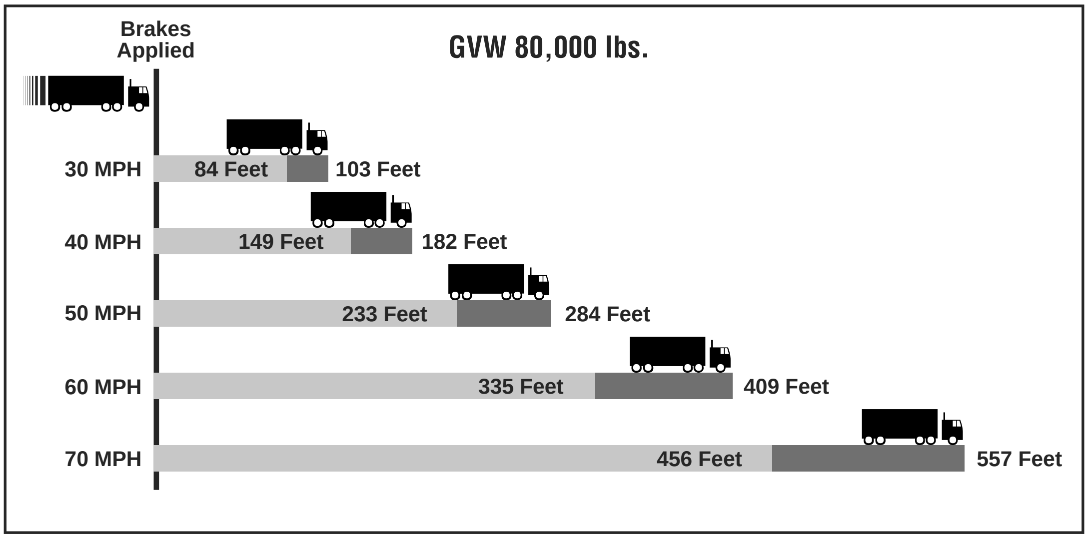
For the sake of discussion let's say the smaller brake assemblies on the steer axle each provide 6% of the brake force for a total of 12% and the other eight larger brake assemblies 11% each for the remaining 88%. Now, what if one of the brake assemblies on the drive axles and one on the trailer aren't getting the job done? These two brake assemblies are using all 2.0" of pushrod stroke and the brake shoes are just barely making contact with the brake drum. Yes we have auto slacks but they can only do their job ***if*** installed correctly ***and*** the foundation brake is in good shape. Each brake assembly accounts for 11% of the total brake force so the loss of two will mean a 22% reduction in brake force. Let's see how that impacts our stopping distances.

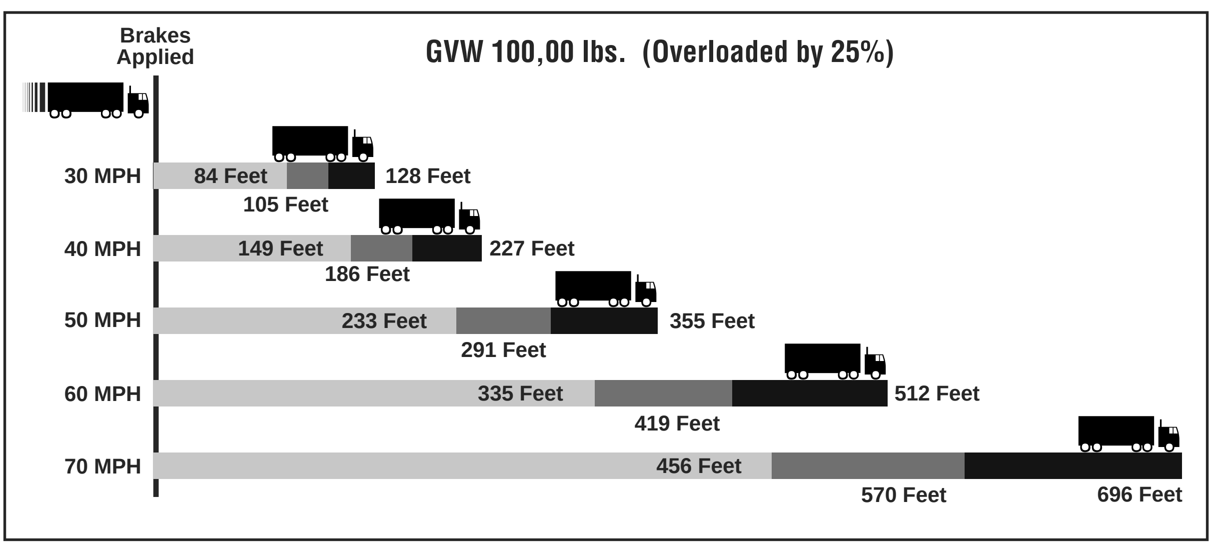
First we'll look at our truck at 80,000lbs GVW -



Effect of Speed on Stopping Distances

Our stopping distance at 60mph is now 409ft, an increase of 74ft which is about one more second down the road. I know I keep reiterating that but none of us really comprehend just how fast we're moving at 88ft/sec until we can't stop in time.

Now let's take a look at the same truck overloaded to 100,000lbs GVW –



Effect of Speed on Stopping Distances — Vehicle Overloaded by 25%

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Originally it took 335ft to stop from 60mph and now it takes 512ft. That's an increase of 177ft which is two seconds farther down the road. That's a lot isn't it? Let's not forget about temperature. Our original hot stop temperature was 475° and we added 25% for overloading which brought it to 594°. Now let's tack on an additional 22% since two of the brake assemblies aren't functioning and our new total is 725° (594° x .22 = 131° so 594° + 131° = 725°). Remember the resin in the friction material begins to boil at 650° so at 725° we're cooking and the brake block is starting to come apart. An OE weight brake drum won't be able to absorb and dissipate the heat fast enough so heat checks are really starting to open up which is like dragging a file across the top of the overworked, overheated friction material. Starting to get a little scary isn't it (to make it really scary just replace the OE weight drums with some of those *"value"* drums and as my grandpa use to say, *"It's pucker time!"*). Anytime a brake assembly isn't functioning its share of the workload is shifted onto the remaining brake assemblies increasing their respective workload. So how often are heavy trucks operating with brakes that are OOS? Let's take a look at some recent inspection data from the FMCSA conducted through the Pennsylvania State Police in 2013 -

Total Commercial Vehicle inspections – 131,156
Total Vehicle OOS Violations – 15,791 (12.04% of the total inspections)
Top OOS Violation – Defective Brakes – 3,160 (20.0% of the total OOS violations)

Violations labeled as defective brakes were most likely due to the pushrod stroke being over 2.0". Obviously the data doesn't go into any detail about what caused the pushrod stroke to exceed 2.0" but I've got four good *"estimations".*

Automatic slacks – Auto slacks become mandatory on new vehicles in 1994. These inspections were conducted 19 years after that change and still 20.0% of the OOS violations were defective brakes. Almost all of the auto slacks I receive back for warranty claim have a broken adjusting rod from the air chamber pushrod being too long as we discussed in the last edition. If an auto slack isn't installed properly it won't work properly.

Foundation brake – The most likely culprit here would be the camshaft spider bushing, especially on drive axles where almost all of the bushings in service are still plastic. Most trailer axle manufacturers since the early 1990's have gone to camshaft spider bushings made of sintered metal. Remember in the last edition about the load the brake drum puts on the roller end of the top shoe driving it into the cam head and forcing it down onto the camshaft spider bushing. That happens every time you apply the brakes.

Brake shoes – Useable lining thickness at or below a ¼". A brake assembly likely being overworked because one or more of the other brake assemblies aren't doing their share of the workload.

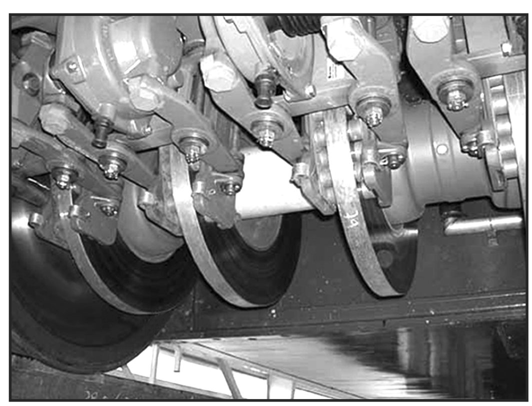
Brake drum – Oversized brake drums worn beyond their 1/8" (0.125") wear limit. 2.0" of pushrod stroke can only compensate for so much wear in the foundation brake. Brake drums should be replaced everytime the brake shoes are replaced.

Remember all that we have discussed here today was still at the old 335ft stopping distance from 60mph. We did ***not*** factor in the 30% reduction down to 250ft. Are you beginning to see a change coming? There are many heavy trucks with s-cam brakes still in service that will need replacement parts for years to come but we are definitely at a crossroads.

Over the next 5-7 years we'll see the s-cam brake gradually phased out on new truck production to be replaced with something much more effective and efficient which is the subject of the next edition of WHEN.

So what could possibly be on the horizon in foundation brakes for heavy trucks? Once again we take our cue from the railroad industry.

As always I hope you found this edition of **WHEN** informative.



Railroad Air Disc Brakes

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