WHEN — Q3 2014
Federal Safety Standards for Heavy Trucks - Part 1

Update #2327

Attention: Dayton Parts' Distributors and Business Partners.

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

For this edition of WHEN I wanted to tackle the new shorter stopping distance requirements for heavy trucks. As I was putting this article together it became evident that we should start at the beginning to get the proper perspective. Due to the volume of information that entails, I decided to split this subject into two parts. ***Part 1*** will take us from the beginning to about 1980. ***Part 2*** will go from 1980 to the present. We'll end up talking about the impact the shorter stopping distances will have and the new "RSD certified" friction materials you've been hearing about. As you read through this edition and the next, you'll see it's a summary of information from a lot of different sources. Making sure that all I wrote herein is accurate took more time than I thought it would and hence the delay. Thanks for your patience and now on to the article.

In the Interest of Public Safety —
In a quest for public safety, government bureaucracy has given birth to a variety of administrations, agencies, boards, regulations, rulings, standards, testing procedures and so on that directly or indirectly determine the braking requirements for the vehicles the heavy duty truck industry manufactures. We have the DOT, FMCSA, FMVSS, NHTSA, NTSB, etc, etc, etc. It's enough "acronym soup" to make you nauseas, eh? First a brief history of how we got to where we are.

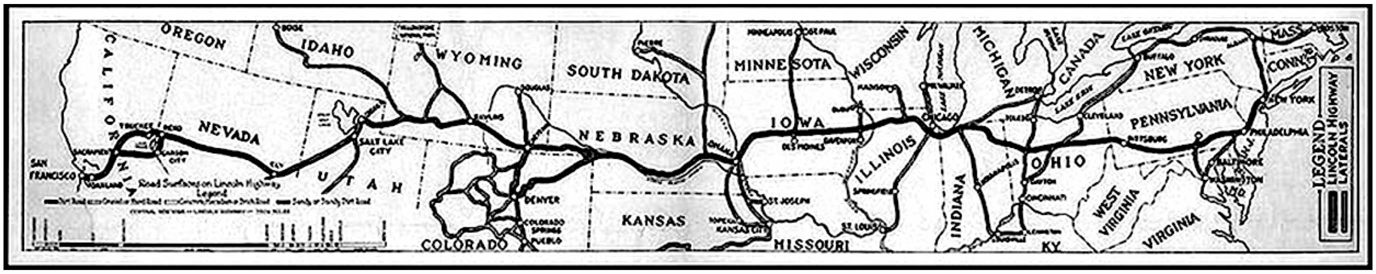
A brief history of the modern transportation industry —
In 1900 the primary means of moving goods and people from one place to another was the railroad. The road system in America consisted mostly of what was inside the limits of a town or city. Outside of these urban areas there were market roads, as they were originally called, that were maintained more or less (and I stress the *less*) by counties or townships. For the most part, these were dirt roads and you *"traveled at your own risk"* as far as the condition of the road on any given day. These county roads as they came to be called were built for local traffic only out into the surrounding rural area. The main mode of personal transportation at that time was still a variety of horse drawn vehicles. As a side note here most of the spring shops in business today can trace their roots back to a blacksmith shop from the *"horse and buggy"* days.

With the introduction of the Ford Model T in 1908, which made the automobile affordable for many people, the advent of the automotive industry changed everything. Not long afterwards we had our first transcontinental highway called the ***Lincoln Highway*** which was strung together using bits and pieces of existing roadways. This highway being put together (you can't say built as more than half of the 3,389 miles were *"not improved"* meaning *"dirt"*) was the passion of one Carl G. Fisher. He was an Indiana native who was an early automotive enthusiast and also the builder of the Indianapolis Motor Speedway (my Hoosier roots are showing through here). On July 7, 1919 the US Army Transcontinental Motor Convoy set out from the White House in Washington, DC, headed for San Francisco using the newly opened *"highway"*. It took this convey almost two months to get to San Francisco averaging just 58 miles a day. Trucks broke down (some things never change, eh?); bridges had to be improved due to the weight of some of the vehicles (overloaded trucks on the highway?) and lots of getting stuck in the mud.

continued on page 2

(continued from page 1)

However there was a young Army lieutenant assigned to this convey and the experience left a lasting impression on him. His name was Dwight David Eisenhower.



The Lincoln Highway — From New York to San Francisco

Eventually this young lieutenant made the rank of general and went on to become the Supreme Commander of the Allied Forces in Europe during WWII. As the US Army made its way across Europe to final victory, this general was thoroughly impressed with the size and construction of the German Autobahn. The ease at which heavy equipment was moved about using this well built network of roads, again made a lasting impression on him. At one time he thought improved two lane roads were good enough for the highways back home but this experience made him see the wisdom of a much *"broader system of ribbons"* across the country.

Later he would carry this vision with him into his US Presidency and would be the main proponent behind the beginning of our interstate highway system. President Eisenhower saw this network of well constructed *"superhighways"* as an important part of our national defense. If the US was ever invaded by a foreign power, the need to be able to move men and equipment around the country in a short amount of time would be paramount. Years later when the first four lane transcontinental highway route was finished, you could travel from the east coast to the west coast in just five to six days. A reduction in travel time of 90%!

The building of this new National System of Interstate and Defense Highways as it was officially called began with the Federal Aid Highway Act of 1956. This Act also established the Federal Highway Trust Fund which we still use today for interstate highway construction and maintenance. As sections of this system were finished and travel among the general population increased dramatically so did the speed of cars and the amount of traffic. In 1966 Senate hearings were held to hear charges brought by Ralph Nader against the automotive industry for not incorporating numerous safety improvements into the vehicles they were manufacturing. These hearings helped garner public support for the federal government to take control of motor vehicle and highway traffic safety. Later in October of that same year President Lyndon Johnson established the Department of Transportation as the umbrella over what would become a plethora of sub-agencies.

The National Traffic and Motor Vehicle Safety Act was passed in 1967 which established the first federal motor vehicle safety standards (FMVSS) that took effect on January 1, 1968. The DOT set-up the National Traffic Safety Agency and the National Highway Safety Agency then quickly consolidated them into the National Highway Safety Bureau (NHSB). Under the Highway Safety Act of 1966 the NHSB issued the first thirteen national highway safety standards.

On December 15, 1967, the Silver Bridge which connected Point Pleasant, WV to Gallipolis, OH collapsed. This bridge was a two lane eye bar suspension design with a 700 ft main span and two 380 ft anchor spans elevated 102 ft above the Ohio River. Thorough failure analysis led to the cause being the suspension eye bar chain design itself as one of the eyes cracked and eventually gave way. The bridge was last inspected on December 6, 1967 just nine days prior to the collapse. Eyewitnesses interviewed afterwards say they heard what sounded like a gunshot and then the entire 1,460 ft suspended portions *"folded like a deck of cards"* in about 20 seconds, taking with it 32 vehicles and 46 victims, two of which were never found. This tragedy brought about national bridge engineering and inspection standards being established as part of the Federal Aid Highway Act of 1968. As another side note the bridge collapse portrayed at the end of the movie *"The Mothman Prophecies"* is based upon what happened at Silver Bridge.

continued on page 3

(continued from page 2)

From here on the history will be interwoven with the subject matter. The federal government and various air brake system manufacturers along with the truck manufacturers begin to engage in a constant debate over standards, rulings, regulations, etc. Nothing wrong with a healthy debate about something as important as safety but as we'll see in some cases, knowing you will always have the final word (like the federal government does) can lead to overreaching. Next an important term used when talking about friction material that needs to be defined before proceeding.

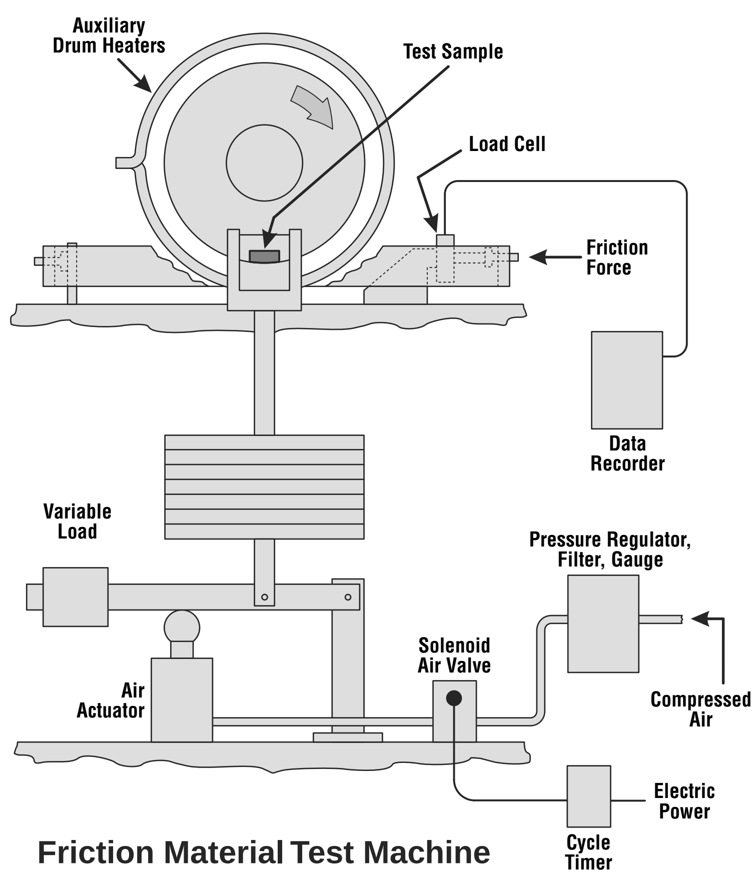
Coefficient of Friction – One of the main values of friction material is the coefficient of friction (COF). The COF is the ratio of force needed to overcome the friction between two surfaces. Here are a couple of examples to illustrate -

1. Let's say you have a 100kg weight sitting on a level surface. In this case the amount of force keeping the weight there is 100 kg (gravity). If it takes 100kg of force to move the weight then the COF is 1.0 (100/100 = 1.0). Now let's say you change the material the weight is sitting on and it only takes 50kg of force to move the weight. The COF for the second material is .50 (50/100 = .50).

2. Now let's say you have the 100kg weight back on the original material but this time you place another 100kg weight on top of the first one. You now have 200kg (100kg x 2) of force keeping the weight there (like increasing the air pressure during a brake application). Now try to move the 200kg of weight with the same 100kg of force. What happens? Nothing, the weight won't move. You'll either have to increase the force you're trying to move it with or change the material and reduce the COF. The COF of the second material was .50 so let's see what that does. 200kg x .50 COF = 100kg and the weight will move.

I realize this is a very simplified illustration of what's going on when you make a brake application but the math doesn't change (it just gets more complicated!). The COF can change with the selection of a different friction material. Another main factor when testing brake performance is temperature as we discussed in the first edition of WHEN with the article on value drums. Now back to the story at hand with the first friction material identification system.

FMSI Edge Code – In 1964 the Friction Materials Standards Institute (FMSI) got a two letter friction material identification system approved based on a Society of Automotive Engineers (SAE) test outlined in 1958. This test uses a 1" square of the friction material to measure the COF within a specified temperature range. The first letter indicates the cold stop COF which is the average of four readings with the drum temperature between 200 and 400 degrees. The second letter indicates the hot stop COF which is an average of 10 readings between 400 and 650 degrees taken over the first fade/recovery and then the second fade/recovery. Here's a diagram of the original friction material test machine –



Friction Material Test Machine

The COF range for each letter code:

C — Not over 0.15
D — Over 0.15 but not over 0.25
E — Over 0.25 but not over 0.35
F — Over 0.35 but not over 0.45
G — Over 0.45 but not over 0.55
H — Over 0.55

SAE Test J661 with identification system outline in J866 used by FMSI

continued on page 4

(continued from page 3)

This system was probably adequate when it was approved in 1964. The Federal Highway Aid Act of 1956 mentioned earlier had set the maximum gross weight allowed on highways at 73,280 lbs but that's it. No braking system or stopping distance requirements existed at this time. However many things have changed since then. The range each letter code represents is far too wide. We can illustrate this by using a brake force calculating formula developed by the National Traffic Safety Board (NTSB) in 1990. The NTSB is an independent agency that was given the authority to regulate the transporting of hazardous materials when President Ford signed the Transportation Safety Act of 1974.

Here's the brake force formula they developed -

$$\text{Brake Force} = \frac{(\text{BSL x PRF x SA x COF x DR}) \text{ x } .6}{(\text{CR x SLR})}$$

BSL = Brake shoe mechanical leverage ratio which for a fixed pivot air brake shoe is 2
PRF = Air chamber pushrod force
SA = Slack adjuster arm drilling the pushrod clevis is attached to, usually 5.5" or 6.0"
COF = Friction material coefficient of friction
DR = Brake drum radius
CR = Camshaft radius which is usually 0.5"
SLR = Static loaded radius of tire(s) when the axle is loaded to the GAWR

Now we'll plug the following numbers into this formula and take a look at a friction material at the very low end of the F code range at 0.36.

BSL = 2
PRF = 970 which is the pushrod force of a type 30 chamber at 2" of stroke at 40 psi.
SA = 5.5" like on a typical drive axle set-up
COF = 0.36 the very low end of the F code range
DR = 8.25" radius of a 16.5" drum
CR = 0.5"
SLR = 19.5 for a 11.00R22.5 tire on a 23,000 lb axle loaded to its GAWR (gross axle weight rating)

$$1{,}950.1 = \frac{(2 \text{ x } 970 \text{ x } 5.5 \text{ x } 0.36 \text{ x } 8.25) \text{ x } .6}{(0.5 \text{ x } 19.5)}$$

Now we'll keep all of the numbers the same except the COF. We'll change it from 0.36 to 0.45 which is the very top of the F code range.

$$2{,}437.7 = \frac{(2 \text{ x } 970 \text{ x } 5.5 \text{ x } 0.45 \text{ x } 8.25) \text{ x } .6}{(0.5 \text{ x } 19.5)}$$

That's a difference of 20% ((1950/2437)-1) in the calculated brake force. Almost all 23k rated friction materials today would be marked FF. Obviously a more specific system is needed in order to make accurate comparisons between different brands/formulas of friction material.

NHTSA and FMVSS-121 - In 1970 the NHSB became the National Highway Traffic Safety Administration (NHTSA) which continues to set safety standards today. In June of 1970 the NHTSA was working on a new proposed regulation for air brake systems on trucks, trailers and buses. The original proposal would have required buses, single unit trucks and empty truck-tractors to meet the same 216 ft stopping distance from 60 mph that passenger cars (FMVSS-135) had to meet. Understand that, the federal government was contemplating going from no standard at all for a vehicle that grosses out at a minimum of 26,000 lbs to the same stopping distance as a passenger car whose average weight in 1970 was 3,700 lbs. I guess they just didn't grasp the difference inside of the whole weight/inertia thing?

This proposal also called for an anti-lock brake system (ABS) that used wheel sensors to automatically control brake torque at one or more wheels during braking. Bear in mind this is in the early 1970's and technology at this time was very limited (the first "PC" wouldn't hit the US retail market for almost ten years). The air brake system manufacturers were just beginning to develop ABS systems and voiced their concerns about reliability, performance and the need for more R&D time. After much debate the NHTSA relaxed the stopping distances to 280 ft for buses and 335 ft for single unit trucks or truck-tractors with a GVWR of 26,000 lbs or more. However the ABS mandate remained and FMVSS-121 was officially implemented on January 1, 1975.

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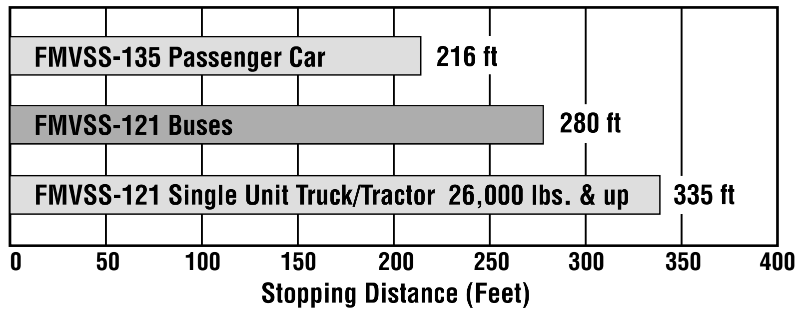
January 1, 1975 — FMVSS-121 Stopping Requirements



FMVSS-121 and the Paccar Decision – Due to the lack of a reliable ABS system, Paccar along with the American Trucking Association (ATA) filed a law suit against the NHTSA claiming there was no proven technology available to meet the FMVSS-121 ABS mandate at that time. In 1978, the 9th Circuit Court of Appeals ruled against the NHTSA and invalidated all of the ABS requirements of FMVSS-121 for trucks and trailers but the stopping distances remained unchanged. So this court decision leads me to ponder the following. A federal court wouldn't rescind the ABS requirements if they were truly essential to meet the newly imposed stopping distances. That would put the safety of the public on the highways at great risk. However the stopping distances were left unchanged and the truck manufacturers still met them without an ABS system. This begs the obvious question, "Why then was an ABS brake system mandated in the first place?"

FMVSS-121 Friction Material Test – All friction material has to pass this test to be considered for OE approval. There are 4 parts to this test **– Brake Effectiveness** (or retardation), **Brake Power** (or fade), **Hot Stop** and **Brake Recovery**. This test is conducted with a wheel load (WL) of either 11.5k for a 23k axle rating or 10.0k for a 20k axle rating depending on which one the friction material is being tested for. A complete brake assembly from the air chamber to the brake drum is used unlike the FMSI/SAE J661 test which used a 1" square of friction material. There is a very specific procedure outlined for how this test is to be done however the friction material manufacturer determines the size of the air chamber, slack arm length and the static loaded radius (SLR) they want to use (sometimes the SLR is referred to as the rolling radius). The test set-up is usually determined by the normal application for the friction material being tested. For example to test 4702 block (15.0" x 4.0" brake size) it most likely would be a type 20 chamber with a 5.5" slack arm length and a SLR of 19.5" for an 11.00R22.5 tire. Another side note here. What if this same 4702 brake assembly was being used with a 19.5" wheel/low profile tire? Would that change the amount of brake force? Sure it would. Tire size has a direct bearing on the amount of brake force since that's how the deceleration of the vehicle gets transferred to the ground.

Back to our brake force formula to illustrate with a few changes -

PRF – changed to 460 to reflect a type 20 chamber at 2" of stroke at 40psi
DR – changed to 7.50" radius of a 15.0" drum

First an 11.00R22.5 tire with a SLR of 19.5"

$$1{,}050.9 = \frac{(2 \times 460 \times 5.5 \times 0.45 \times 7.50) \times .6}{(0.5 \times 19.5)}$$

Next a 265/70R19.5 tire with a SLR of 15.9"

$$1{,}288.9 = \frac{(2 \times 460 \times 5.5 \times 0.45 \times 7.50) \times .6}{(0.5 \times 15.9)}$$

continued on page 6

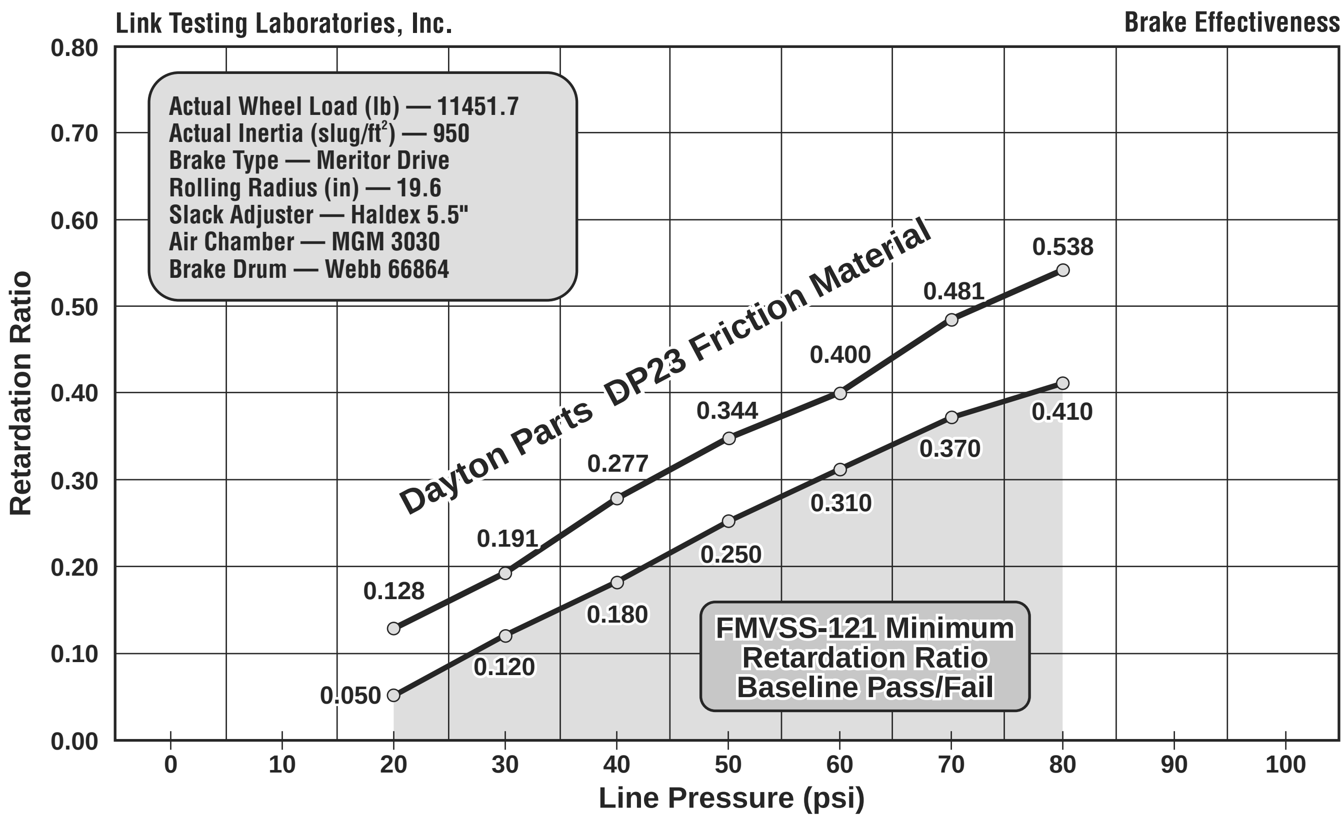
(continued from page 5)

That's an 18.4% ((1,051/1,288)-1) difference in the amount of brake force with just a change in tire size. Conversely if you were to take off 22.5" tires and replace them with 24.5" (maybe looking for better fuel economy) you would also reduce the amount of brake force accordingly at the pavement.

For 4707 block the set-up would most likely be a type 30 chamber, 5.5" slack arm length and again a 19.5 SLR for an 11.00R22.5 tire. Since 4707 can be used on a drive or trailer axle, the drive axle set-up with the lower AL factor (slack arm length x air chamber type) is a more accurate test. Whenever you see test results for block that can be used on a drive or trailer axle (4515, 4707) using a 6.0" slack arm like on a typical trailer brake set-up understand that's *"enhancing"* the results somewhat.

Brake Effectiveness - After a specified burnishing procedure, which we won't go into detail here, this part of the test is done with the drum temperature between 150 and 200 degrees. The brake assembly is brought to a speed of 50 mph and then a stop is conducted with a constant air chamber pressure of 20 psi. The average torque exerted by the brake is measured from the time the specified air pressure is reached until the brake stops. This torque value is then divided by the (SLR x WL) to determine the retardation ratio (remember this when we get to RP628 in Part 2). The drum is then brought back to the 150 to 200 degree temperature range and the test is repeated 6 more times, while increasing the air pressure in 10 psi intervals up to and including 80 psi.

Here's a typical brake effectiveness graph plotting the test results —



This part of the test is to confirm that the friction material can generate a sufficient amount of brake torque throughout the pressure range of the air chamber when high temperature is not a factor. The line you see starting at .050 and ending at 0.41 is the minimum baseline for compliance as set by FMVSS-121. In other words it's simply a pass or fail. The result of this part of the overall test in no way determines whether a friction material is *"economy"* or *"premium"* and so forth. However a higher retardation ratio would indicate a higher COF.

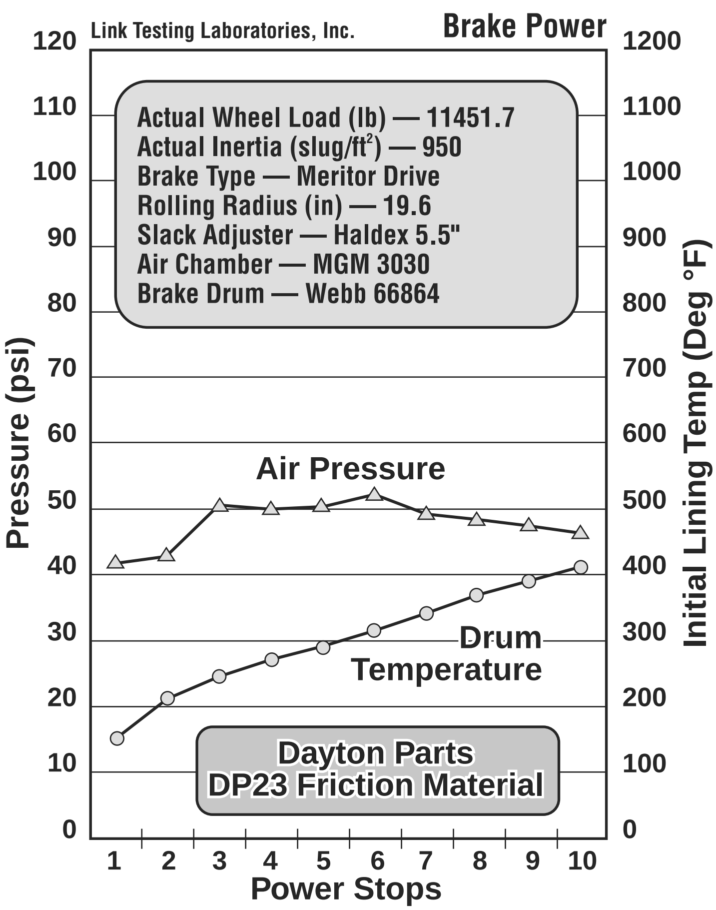
continued on page 7

(continued from page 6)

Another side note here (again). When comparing two different friction materials, if you don't know the actual COF of each one, you could substitute this ratio value in place of the COF when using the brake force formula. Granted it's not the actual COF but for comparison purposes it would illustrate the difference between the two materials. Just make sure you use the retardation ratio from the same psi application (say like at 40 psi) for both materials so you're making an *"apples to apples"* comparison.

Brake Power – This part of the test also starts with the drum temperature at 150 to 200 degrees. The brake assembly makes a series of 10 consecutive stops from 50 mph to 15 mph at a deceleration rate of $9ft/sec^2$. Upon reaching 15 mph the brake is released and the assembly accelerates back to 50 mph. 72 seconds after the start of the first deceleration the brake is applied again in the same fashion for the second stop and so on until all 10 stops are completed. During this test the air line pressure and drum temperature are recorded. The air line pressure cannot exceed 100 psi during any deceleration. Temperature is also recorded but is not part of the test criteria. Generally the drum temperature will rise to between 400 and 450 degrees by the 10^{th} stop. In comparison to the original FMSI/SAE J661 test, the second letter code for the hot stop COF was taken at a drum temperature between 400 and 650 degrees.

Here's what a typical brake power graph looks like.



This part of the test tells us if the friction material can continue to create sufficient torque as the brake temperature rises. A rise in air line pressure is normal as this *"fade"* warns the driver that his brakes are getting hotter because he has to apply more air pressure to achieve the same amount of braking power. The max air pressure allowed is set at 100 psi because air governors are set to *"cut-out"* at 105 psi and therefore the air system's max pressure available.

Hot Stop – One minute after the last deceleration is completed for the brake power test the drum is brought to a speed of 20 mph and a complete stop is made at a deceleration rate of $14ft/sec^2$. Air line pressure and drum temperature are again recorded.

Brake Recovery – Two minutes after the hot stop is completed the brake assembly must make 20 consecutive stops from 30 mph to 0 mph at a deceleration rate of $12ft/sec^2$. The stops are at equal intervals of 60 seconds from the beginning of one stop to the beginning of the next until all 20 stops are completed. During this part of the test air line pressure and drum temperature are recorded. The air line pressure needed to achieve the $12ft/sec^2$ deceleration rate cannot exceed 85 psi nor be less than 20 psi. Drum temperatures will usually hover between 400 and 450 degrees and may begin to slowly drop. *(see the chart on the next page.)*

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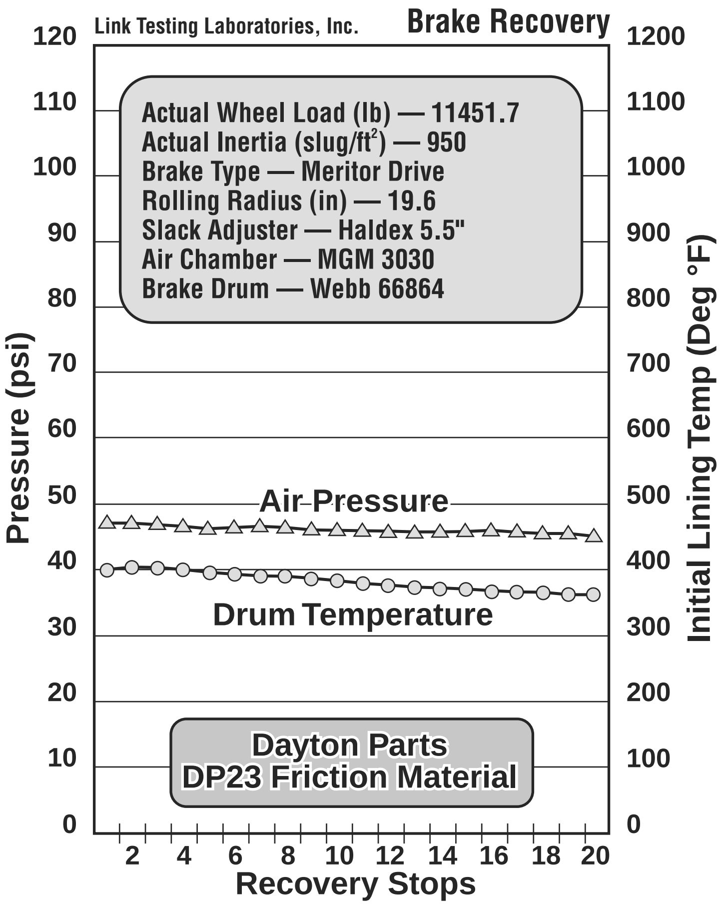
Brake Recovery – (continued)

Here's what a typical brake recovery graph looks like.



This part of the test tells us if the friction material can continue to create sufficient torque after it has been subjected to higher drum temperatures. The 20 psi minimum is really a mute point now that ABS is once again mandated *(more about that in Part 2).*

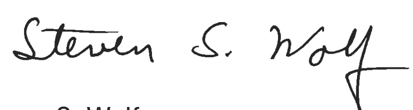
One last side note here. While reading through how this test is conducted, the ability of the brake drum to dissipate heat in a sufficient manner becomes very obvious. You would not get the same results shown in the charts here with a *"value"* drum.

In closing remember this test is only required for friction materials that are seeking OE approval. Aftermarket friction materials are not required to have this test done in order to be sold. Most aftermarket friction material manufacturers do have this test done on their own accord which is good.

Never purchase any friction material where this test cannot be supplied. In the next edition we'll pick up where we left off around 1980 and go to the present plus a look beyond.

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

Regards,



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Look for the Part 2 continuation
of this edition of **WHEN** in the
Q4 Dayton Parts Distributor Mailing