THE FEDERAL REDUCED STOPPING DISTANCE MANDATE: IMPACT AND SOLUTIONS
UPDATED AUGUST 2013

Bendix Spicer Foundation Brake LLC
901 Cleveland Street • Elyria, Ohio 44035
1-866-610-9709 • www.foundationbrakes.com
# Table of Contents

1 : Important Terms .................................................. 3-4

2 : Executive Summary ............................................. 5-6

3 : Industry Trends in Braking ....................................... 7-10

4 : Understanding the New Stopping Distance Requirements ........ 11-14

5 : Braking Solutions .................................................. 15-21

6 : Meeting the Reduced Stopping Distance Mandate ............... 22-27

7 : What the Mandate Means for the Industry ....................... 28-31

8 : Importance of Choosing OEM Replacement Parts .................. 32-33

9 : Conclusion .......................................................... 34

9 : About the Authors .................................................. 35
To aid your understanding of the content in this white paper, Bendix has compiled a list of key terms and definitions.

**Panic Stop Braking**
The new stopping distance regulation was developed to improve performance during panic stop braking, which is the ability of a vehicle to stop quickly under emergency conditions.

**Kinetic Energy**
Energy associated with motion. The greater a vehicle’s kinetic energy, the greater the braking force needed to slow the vehicle. Kinetic energy is defined by the equation $KE = \frac{1}{2}MV^2$, in which $KE$ is kinetic energy, $M$ is mass or load, and $V$ is velocity or speed.

**Thermal Capacity**
The amount of heat the brake system can retain.

**Heat Dissipation Rate**
The rate at which the brake system converts kinetic energy into heat and releases it into the atmosphere.

**Torque**
Braking force.

**Brake Fade**
The condition in which the thermal capacity of the braking system has been exceeded and the system operates at reduced effectiveness.

**Hysteresis**
The lag in response between brake actuation and functioning.

**High-Performance Drum Brakes**
Foundation drum brakes engineered to develop the increased torque necessary for shorter stops, with features such as greater width, larger chambers, and additional lining.
**Performance Metrics**

Key brake performance categories of torque, weight, and fade.

**Independent Wheel Control**

A characteristic of full electronic stability systems that enhances a vehicle’s ability to meet the stopping distance requirement.

**Combination Lining**

Specially formulated friction material for maximum brake lining performance and longevity.
The United States and Canada have long emphasized their goal to more closely align the stopping-distance requirements for passenger cars and heavy trucks for increased highway safety. They point to the difference in size between large trucks and passenger vehicles as a leading factor in the intensity of highway accidents.

In its Dec. 15, 2005, notice of proposed rulemaking (NPRM) to improve the stopping distance performance of truck tractors, the National Highway Traffic Safety Administration (NHTSA) stated that while large trucks operate on the same roadways as significantly lighter passenger vehicles, they may take twice as long to stop in instances of panic stop braking. In its proposal, NHTSA called for a 20 to 30 percent reduction in the required stopping distance for large trucks.

Bendix Spicer Foundation Brake LLC and Bendix Commercial Vehicle Systems LLC together maintained a position that, for the sake of highway safety, NHTSA should rule in favor of the maximum 30 percent reduction to shorten the stopping distance for large truck tractors. This 30 percent reduction, decreasing the maximum stopping distance for the vast majority of large commercial vehicles from 355 feet to 250 feet, would bring the trucks more in line with passenger cars. The incremental benefit in terms of lives saved, accidents prevented, and property damage mitigated would be significantly greater than the cost of implementing a 30 percent reduction.

After extensive studies and industry outreach, NHTSA decided on a 30 percent reduction, announcing its final rule in July 2009. The agency determined that the transition to the new requirements would occur in two phases, with compliance dates of Aug. 1, 2011, and Aug. 1, 2013, depending on vehicle type. Phase one comprises the majority of commercial vehicles on the road today.

A variety of solutions are available to accommodate the level of reduction required in both phases. The solutions are the result of intensive, ongoing brake system development, testing, and validation efforts that began years before the final rule was announced.
In this paper, we will discuss the specifics of the federal reduced stopping distance mandate. The paper will outline how the ruling fits within the broader context of industry braking trends, examine the evolution and details of the mandate, note solutions that meet the requirements, and explore the mandate’s impact on the trucking industry.

Specific topics consist of:

**Industry Trends in Braking**
Factors affecting the development of braking systems today include stronger vehicle regulation and enforcement – such as Compliance, Safety, Accountability (CSA) – and increased focus on proper truck maintenance.

**Understanding the New Stopping Distance Requirements**
How the federal mandate evolved, its requirements, and anticipated benefits.

**Braking Solutions**
A primer on foundation brakes – the forms they take, the physics behind them, and the vehicle factors that affect their capabilities – as well as advances in braking technology.

**Meeting the Reduced Stopping Distance Mandate**
A wide variety of configurations will meet the requirements, but one solution will be chosen most often. And, while not required, the solution of air disc brakes will best optimize vehicle safety.

**What the Mandate Means for the Industry**
The impact of the new rule on OEMs and the vehicles they produce, fleets and owner-operators, and the aftermarket. Also, the value proposition of higher-performing brakes.

**Importance of Choosing OEM Replacement Parts**
For the safest trucks that are always up to OEM standards, choosing only original equipment replacement parts is essential. Spec’ing the proper replacement brake linings is especially critical.
The federal mandate for reduced stopping distance is best understood within the broader context of industry braking trends.

**Stronger Regulation and Enforcement**

The reduced stopping distance legislation is among a number of recent laws and regulations having an impact on braking systems and the commercial vehicle industry as a whole.

One initiative in particular is having a sweeping effect on the industry. **Compliance, Safety, Accountability (CSA)** is a highway safety initiative of the Federal Motor Carrier Safety Administration (FMCSA). Implemented in December 2010, CSA is a new nationwide regulatory system that will lead to a considerable increase in the number of safety assessments of commercial vehicles, with the results open for public examination. The base goal of CSA is to help reduce crashes, injuries, and fatalities involving commercial vehicles.

As described by the FMCSA, CSA introduced a new safety and compliance model that will significantly increase scrutiny on fleets, owner-operators, and individual drivers regarding matters of safety. The agency and its state partners have the power to contact and assess a larger number of carriers — and intervene when necessary — in order to address safety issues before crashes happen. For the first time, the safety performance of individual drivers will be assessed, along with the performance of carriers.

CSA represents a major change for the industry. In this stringent federal safety landscape, odds are now higher that carriers and drivers will be assessed by the government. The assessment information, available to the public, will be examined by companies hiring fleets and fleet managers hiring drivers. Through this action, the FMCSA is forcing carriers and drivers to be accountable for their safety performance.

More regulations specifically affecting brakes reduce the amount of copper allowed in brake friction materials.
In March 2010, Washington became the first state to pass legislation in an effort to protect its waterways from the runoff of toxic copper brake dust. California also passed a bill, which became law in September 2010. Similar legislation is underway in other states.

The California law mandates that brakes contain no more than 5 percent copper beginning in 2021. By 2025, the limit will be reduced to 0.5 percent. Washington’s law is similar, with a 5 percent limit by 2021, and the establishment of an advisory committee to assess the feasibility of lowering the limit to 0.5 percent in subsequent years.

The Brake Manufacturers Council is an operating council of the Motor & Equipment Manufacturers Association (MEMA). MEMA, on behalf of the council, has helped to shape the copper debate and legislation. The association applauded the signing of California’s bill. Bendix Spicer Foundation Brake, a member of the council, supported the legislation as well. The company’s lineup of Bendix® brand foundation drum brakes – available on a full range of OEM models today – already meets the new state mandates for 2021.

Though not specific to braking systems, the federal government’s increasingly stringent emissions standards are also exerting additional performance and cost pressures on the industry. Environmental Protection Agency (EPA) regulations in 2007 and 2010 dramatically reduced the allowable discharge of fuel nitrogen oxides (NOx) and diesel particulate matter (PM).

OEMs responded to EPA ’07 and ’10 with major technical advances to their vehicle systems. These advances – including advanced exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and the diesel particulate filter (DPF) – have added a total of $10,000 to $15,000 to the cost of each commercial vehicle.

Additional emissions regulations took effect in August 2011, when NHTSA and the EPA jointly issued a final rule establishing a comprehensive Heavy-Duty National Program. The HD National Program is intended to reduce greenhouse gas emissions and increase fuel efficiency in commercial medium- and heavy-duty vehicles manufactured between 2014 and 2018. Government agencies – NHTSA and the EPA – are working on the second phase of the HD National Program for post-2018 model year vehicles.
Increased Focus on Proper Vehicle Maintenance

The recent laws and regulations affecting commercial vehicles are increasing the focus on proper maintenance of vehicles, including brake systems. As attention turns to new solutions to meet safety and fuel economy standards, robust maintenance practices grow in importance. Robust practices are necessary for vehicles to pass assessments and perform optimally, while protecting the investment of fleets and owner-operators.

Increased Demand for Braking

The evolution of commercial vehicles has resulted in increased braking demands. For example, design changes have made trucks more aerodynamic. Drivetrain losses have decreased significantly. Tire technology has improved considerably. As these kinds of advances occur, brake systems must do more work.

And as demand for braking increases, so does the demand for ways to offset the higher cost of more braking power – such as lighter-weight brakes, reduced maintenance times, and longer service intervals. The industry continues to advance the technology of large-truck brake systems to meet these demands. In the “Braking Solutions” section of this paper, we discuss specific advances.

Increased Use of Air Disc Brakes

While already highly utilized in Europe and in select North American applications, air disc brakes are experiencing continued growth in popularity on North American highways with commercial vehicle fleets and owner-operators. Previously considered a niche technology for bus, coach, fire trucks, and other special applications, air disc brakes are becoming increasingly sought out for over-the-road applications.
Bendix experienced a nearly 120 percent increase in demand for these advanced braking systems from 2009 to 2010. The company added a new assembly line in 2011 to meet increasing demand. In early 2012, Bendix Spicer Foundation Brake reached the quarter-million milestone on the brake, which it began producing in 2005. The company surpassed the 400,000-unit mark in early 2013, an increase of more than 60 percent in just one year.

Industrywide, air disc brakes represent only a 10 percent market share, with drum brakes encompassing 90 percent. Their acceptance is clearly growing, however, as evidenced by the ever-increasing output at Bendix. The industry is increasingly demanding air disc brakes and the higher performance and safety they offer, as well as their reduced maintenance demands.
Evolution of the Federal Mandate

On March 10, 1995, NHTSA published Federal Motor Vehicle Safety Standard (FMVSS) No. 121, Air Brake Systems. In part, this rule re-established stopping distance requirements for medium and heavy trucks. The mandate replaced earlier stopping distance requirements that had been invalidated in 1978 because of reliability issues with antilock braking systems.

Under FMVSS No. 121, stopping distance requirements varied according to vehicle type. Most truck tractors were required to stop within 355 feet when tested at 60 mph while pulling an unbraked control trailer in the loaded-to-GVWR (gross vehicle weight rating) condition. Unloaded, truck tractors were required to stop within 335 feet.

A decade later, NHTSA set out to update the rules. On Dec. 15, 2005, the agency published an NPRM to amend FMVSS No. 121. NHTSA sought to reduce stopping distance by 20 to 30 percent.
The agency moved to amend the braking standard to reduce the number of fatalities and injuries associated with crashes involving heavy trucks and other vehicles. NHTSA also anticipated that the stricter standard would lessen property damage by averting crashes or reducing their severity.

On July 24, 2009, the agency published the amended FMVSS No. 121. The final rule, which came after consideration of public comments on the NPRM, reduces by 30 percent the maximum stopping distance for nearly all heavy trucks. The stopping distance requirement is reduced by a smaller amount for a small number of very heavy, severe-service tractors.

The amended FMVSS No. 121 applies only to service brake stopping distance. NHTSA did not amend requirements for emergency braking distance.

Designed to implement in two phases, the rule affects the majority of the roughly 300,000 tractors manufactured annually. It applies to truck tractors manufactured on or after the implementation dates of Aug. 1, 2011, and Aug. 1, 2013, depending on vehicle type.

Omitted from the rule are single-unit trucks, trailers, and buses, as well as vehicles produced before the implementation dates.

Requirements of the Final Rule

As outlined in the updated FMVSS No. 121, stopping distance requirements for truck tractors in the loaded-to-GVWR condition tested at 60 mph while pulling an unbraked control trailer are as follows:
For heavy trucks in the unloaded condition, the agency has reduced the specified stopping distance from 60 mph by 30 percent, from 335 feet to 235 feet. This requirement applies to all tractors.

According to NHTSA, it drafted the final rule to “advance the safety and braking performance of truck tractors without imposing overly high costs on the trucking industry or requiring technical advances beyond what are available in the commercial market today.”

Concerning technical advances, NHTSA determined that a 30 percent reduction currently is not feasible for a small percentage – estimated at approximately 1 percent – of severe-service tractors in the loaded condition, specifically three-axle tractors over 70,000 lbs. GVWR and tractors with four or more axles and GVWR exceeding 85,000 lbs. Even with air disc brakes on all wheels, testing demonstrated that these vehicles were unable to meet the 30 percent stopping distance reduction. As a result, the agency implemented a 13 percent reduction for these vehicles.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Axle Configuration</th>
<th>GVWR</th>
<th>New Requirement</th>
<th>Old Requirement</th>
<th>Compliance Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard 6x4 tractors</td>
<td>Less than or equal to 59,600 lbs.</td>
<td>250 feet</td>
<td>355 feet</td>
<td>Aug. 1, 2011</td>
</tr>
<tr>
<td></td>
<td>2-axle</td>
<td>All</td>
<td>250 feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6x4 Severe Service Tractors</td>
<td>Above 59,600 lbs. and less than or equal to 70,000 lbs.</td>
<td>250 feet</td>
<td>355 feet</td>
<td>Aug. 1, 2013</td>
</tr>
<tr>
<td></td>
<td>6x4 Severe Service Tractors</td>
<td>Above 70,000 lbs.</td>
<td>310 feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tractors with 4 or more axles</td>
<td>Less than or equal to 85,000 lbs.</td>
<td>250 feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tractors with 4 or more axles</td>
<td>Above 85,000 lbs.</td>
<td>310 feet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: National Highway Traffic Safety Administration
For all the vehicle types included in phase two of the final rule, the agency determined that the new stopping distances can be met by improved brake systems. However, NHTSA gave manufacturers additional lead time to fully test and validate new brake systems, as only limited developmental work had been performed. The agency wanted the manufacturers to ensure compatibility with existing trailers and converter dollies when used in multi-trailer combinations. NHTSA also wanted to minimize the risk of issues around vehicle stability and control.

**Expected Benefits of Reduced Stopping Distances**

According to the FMCSA, 3,757 people were killed in crashes involving large trucks in 2011, the most recent year for which statistics are available. During 2010, 3,686 people died in truck crashes. In 2011, 88,000 people were injured in large-truck accidents; in 2010, 80,000 people were injured.

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>3,757</td>
<td>88,000</td>
</tr>
<tr>
<td>2010</td>
<td>3,686</td>
<td>80,000</td>
</tr>
</tbody>
</table>

*Source: Federal Motor Carrier Safety Administration*

As estimated by NHTSA, once all heavy truck tractors on the road are equipped with enhanced braking systems capable of meeting the new stopping distance requirements, approximately 227 lives will be saved and 300 serious injuries will be prevented annually.

In terms of property damage, NHTSA estimates an annual savings of more than $169 million. This amount alone is expected to exceed the total cost to fleets and owner-operators seeking new technology to meet the rule. With increased braking power, drivers in panic situations may be able to avert many collisions that, in the past, were often unavoidable.
The foundation brake – the braking mechanism located at the end of each axle – is at the core of the solutions to meet the new federal requirements for reduced stopping distance. It generally consists of an air service chamber, a spring brake chamber, or both; a mechanical brake mechanism; and friction material. The most common types of foundation brakes are S-cam drum brakes and air disc brakes.

The Physics of Foundation Brakes

To fully appreciate foundation brakes, it’s useful to understand how they have evolved, and that starts with a discussion of braking physics.

A fundamental rule of physics, the Law of Conservation of Energy asserts that the total amount of energy in the universe remains constant over time. A corollary to this law is that energy can neither be created nor destroyed; it can only be transformed from one state to another. This fundamental rule also applies to heavy truck engines and brake systems. In the case of the diesel engine, the potential energy – energy stored in a body – is the diesel stored in the fuel tank. This potential energy is converted to kinetic energy by the engine and drive train. Kinetic energy is energy associated with motion. While the drivetrain’s key role is to move the vehicle, it is the primary responsibility of the braking system to bring it to a stop.

Another concept to understand is the energy equation. The role of the foundation brake is to reduce the velocity of the vehicle. The heavier the load and higher the speed, the greater the kinetic energy and, subsequently, the greater the braking demand is to achieve this reduced velocity.

Kinetic energy is defined by the equation: KE = ½MV^2. In this equation, KE is kinetic energy, M is mass or load, and V is velocity or speed.

When considering this equation, two ideas are clear: one, the impact of vehicle weight on braking demand is significant, but linear; and, two, the impact of speed on brake demand is exponential. When factoring in the Law of Conservation of Energy, the kinetic energy of the moving vehicle must somehow be transformed as the vehicle slows and eventually stops. In the case of the braking system, this energy is transferred into work and heat.

The ability to generate the required torque to slow the vehicle – and then dissipate this heat into the atmosphere – becomes the most important function of any vehicle braking system.
As the brake system converts energy into heat, two factors become important: the amount of heat the system can retain – commonly referred to as **thermal capacity**; and, the rate at which it releases that heat into the atmosphere, known as the **heat dissipation rate**. To illustrate this point, we can use the analogy of a common bathtub.

![Brake System Analogy](image)

**Source:** Bendix Spicer Foundation Brake

In the bathtub illustration, the amount of water the tub can hold is its capacity. In the case of the braking system, thermal capacity is largely dependent upon the size, shape, and material of the drum or rotor. Drum and rotor materials are primarily made of cast iron, an economic material that provides the needed thermal capacity. Lighter-weight drum designs use less cast iron – or a combination of iron and steel – to achieve reduced weight. Unfortunately, this weight reduction comes at the expense of the system’s thermal capacity.

Continuing with the bathtub analogy, the rate at which water is added to the tub by the faucet is similar to the rate at which the braking system adds heat to its capacity as it transforms energy into heat during active braking. As the brakes are applied and the vehicle slows down, the temperature increases.

In this example, as water continues to fill the tub, the drain simultaneously removes water, preventing it from overflowing. In a steady-state condition, the tub must drain faster than the faucet adds water. The function of the drain is similar to the brake system’s objective to dissipate heat. An example of how this analogy applies to the braking system is illustrated in sustained downhill braking. In this situation, the brakes are used constantly, adding heat to the system over a sustained period of time without the luxury of a complete cool down.

**The ability to generate the required torque to slow the vehicle – and then dissipate this heat into the atmosphere – becomes the most important function of any vehicle braking system.**
Going back once again to the bathtub illustration, if the drain is unable to keep pace with the rate at which water is being added, the tub will overflow. Overflowing water means that the capacity of the system has been exceeded. This is parallel to the braking phenomena known as **fade**. Fade is the condition in which the thermal capacity of the braking system has been exceeded and the system operates at reduced effectiveness.

**S-Cam Foundation Drum Brakes**

The most common type of foundation drum brake is the S-cam drum brake, commonly referred to a cam – or drum – brake. In a cam-type foundation drum brake, the pneumatic system is linked by an air line to the air service chamber, spring brake chamber, or both. The chamber is then connected to the arm of a slack adjuster by a push rod and clevis. The slack adjuster is installed on the spline of the forged brake camshaft. The slack adjuster acts as a lever, converting linear force of the chamber push rod into a torsional force needed to apply the brakes.

*Source: Bendix Spicer Foundation Brake*
Since 1995, all air-brake equipped vehicles in the United States and Canada have been required to use automatic slack adjusters, commonly referred to as ASAs, automatic brake adjusters or simply slack adjusters. The ASA keeps the brake in constant adjustment by advancing the camshaft forward as the friction material wears.

As the slack moves to and from its reference point, it advances its position as the specified brake application stroke is exceeded. This helps the vehicle maintain a reasonable brake stroke as the brake lining wears. The ASA is integrated into the brake lever and is generally mounted toward the inboard side of the chassis, along with the air chamber and parking brake.

When torque is applied to the camshaft, the “S” shape on one end of the cam spreads the brake shoes, forcing the brake lining into contact with the brake drum, thereby slowing or stopping the vehicle.

Drum brakes are offered in various drum diameters to meet vehicle braking requirements, with the most commonly encountered being the 16½-inch versions. The drum brake has a “leading-trailing” shoe design, with one or more fixed anchor points for the shoes, opposite the cam end of the shoe.

The structure of cam-actuated brakes generally consists of stamped-steel brake shoes and spiders for standard-duty applications, and cast shoes and spiders for heavy-duty applications.

When cam-actuated drum brakes are applied, the friction material contacts the brake drum. The friction between the lining and drum effectively converts the kinetic energy of the vehicle into thermal energy, heating up the brake drum and lining. The friction material and brake drum must have the capability of withstanding the heat until dissipated. It takes the right combination of ingredients to provide all the desirable characteristics. These characteristics include having a torque output sufficient to stop the vehicle, long lining life, long drum life, and quiet operation.
All friction material is rated and identified by stenciled codes on its edge. These codes consist of the name or brand of the manufacturer, the formula identification, the specific part number, and usually two letters designating the lining’s general friction level (examples: EF, FG). It should be noted that these stenciled letters are not considered to be accurate enough for choosing replacement linings. Either genuine original equipment linings should be used or an approved material recommended by the brake and vehicle manufacturers.

Selecting the ideal friction material is dependent upon how the duty cycle, the terrain traveled, and vehicle load, among other factors. The various formulations of material are designed to meet the different needs of these conditions. For example, a vehicle performing heavy-duty operations on rugged terrain will likely be built with a friction material engineered to handle high loads and the needs of severe service applications instead of a “standard” material designed for lighter-duty operations.

**Air Disc Brakes**

Air disc brakes – often referred to as ADBs or disc brakes – convert air pressure into braking force. When the foot brake is applied, air from the vehicle brake system enters the service brake chamber through the supply port, applying pressure to the diaphragm. The pressure pushes the diaphragm, moving the pressure plate and pushrod against a cup in the lever. The lever pivots on an eccentric bearing and transfers motion to the actuating beam.

Moving against return spring force, the actuating beam moves two threaded tubes and tappets, which force the inner brake pad into contact with the brake rotor. Further movement of the actuating beam forces the caliper, sliding on two stationary guide pins, away from the rotor, which pulls the outer brake pad into the rotor. The clamping action of the brake pads on the rotor applies braking force to the wheel.

Releasing the foot brake releases pressure in the service brake chamber. With no pressure in the service brake chamber, return springs force the air disc brakes into a neutral, non-braked position. The non-braked position is mechanically controlled by a brake adjuster mechanism in the caliper.
The caliper contains a brake adjuster mechanism that turns threaded tubes to set a gap (running clearance) between the rotor and the brake pads. When operated manually with the adjuster shaft, the adjuster mechanism sets the system’s non-braked position. The adjuster mechanism also operates automatically whenever the brakes are activated to compensate for rotor and brake pad wear and to keep the running clearance constant.

The combination of rotor and friction materials (friction-couple) is carefully designed for optimal performance and durability. It is recommended that only original equipment or approved replacement disc pads and rotors be used to prevent performance and durability problems (e.g. cracked rotors) or premature or uneven pad wear, which can adversely affect braking performance and safety.

**Advances in Braking Technology**

Today’s brakes look like their predecessors, but in reality, they are very different. The technology has changed dramatically. This is especially true of friction materials. Of all the developments in brake technology during the last 25 years, the most significant is the friction material used in brake linings.

When the use of asbestos ended in the mid 1980s, the challenge began to find other materials to use in brake linings. The industry has become adept at understanding lining formulations and the interactivity of ingredients. Engineers also learned more about the duty cycle of friction materials and what they are exposed to on the road, so longer-wearing solutions could be developed.
Soon after the transition away from asbestos linings, drum brake linings lasted less than 250,000 miles for a typical line haul application. Today, it is very common for line haul tractors to go 600,000 miles before the linings wear out. Air disc brake linings are performing even better and it is common for ADB-equipped line haul tractors to go 1 million miles between pad changes.

Other significant braking technology advances have occurred with drum brakes. High performance drum brakes, engineered to develop the increased torque necessary for shorter stops, feature several enhancements:

- **Larger chambers** – 24-square inch diaphragms with long stroke (3 inch stroke) vs. 20-square inch standard stroke (2½ inch stroke).
- **Precision camshaft journals**, an improvement of the brake’s geometry that helps reduce variation and improve overall braking performance.
- **Greater width** for increased braking surface, improved heat dissipation, reduced fade, longer life, and lower cost per mile.
- **More wearable lining** for longer life.

The stopping distance for Bendix® high performance drum brakes equipped with OEM high performance friction is 35 feet less than the mandate’s requirement of 250 feet, demonstrating the ability of these brakes to far exceed the new reduced stopping distance standards.
Every Operation Is Different

Many variables dictate which braking system should be chosen to meet the new stopping distance requirements. What the truck is carrying, where it’s running, how many miles it’s covering, and how many stops it must make are just a few of the factors to consider when choosing the braking system that will work best. Because every operation is different, unique solutions, rather than one-size-fits-all systems, are necessary.

Among the variables is the vehicle configuration itself. Vehicle factors have a major impact on a large truck’s braking capability. Four key variables should be considered when specifying a braking system that meets the federal mandate:

- **Gross axle weight rating** – the rated weight of a single or multiple axle set in cases of tandems (2 axles) or tridems (3 axles).
- **Wheelbase** – a measurement from the front axle to the center of the rear drive axle(s).
- **Tire size** – the larger the tire, the greater the inertia and more difficult it is to stop.
- **Center of gravity** – where the center point of the load resides within the vehicle.

---

**Top-of-Mind Considerations**

When Spec’ing a New Truck

1. Larger, more powerful steer-axle brakes will meet the mandate in most cases.
2. From a wide variety of configurations, choose the best option for your operation.
3. Look at your costs and accident rate, and then decide if the added investment for disc brakes makes sense.

When Changing Out a Truck

1. Foundation brakes today can accommodate the dimension of larger drum brakes or disc brakes and ensure the proper fit within the existing wheel-end envelope.
2. Insist on original equipment replacement parts.
3. Consider retrofit kits.
Those vehicle factors, along with a truck’s operational variables, all play a part in a vehicle’s ability to stop. They ultimately will determine the optimal braking solution.

**Wide Variety of Configurations Will Work**

Extensive vehicle test data confirms that through a wide variety of foundation brake configurations – including all drum brakes, all disc brakes, or a combination of both – vehicles can meet or exceed a 30 percent reduction requirement. In fact, truck tractors fitted with Bendix disc brakes have consistently shown the ability to stop within today’s regulatory standard for passenger cars (216 feet).

Foundation brakes are being manufactured today to accommodate the dimension of larger drum brakes or disc brakes and ensure the proper fit within the existing wheel-end envelope.

**Typical Solution: Steer-Axle Brake Upgrade**

In general, the new federal stopping distance legislation means the use of larger, more powerful brakes and advanced friction materials, particularly on steer axles. The drive axle brakes can be upgraded as well, but such an upgrade often isn’t necessary. In most cases, trailer brakes will remain unchanged.

The most typical solution is to upgrade steer axles to higher performing drum brakes. There are two reasons for this choice: One, it’s technically possible to meet the new rule with these wider, enhanced drum brakes; and two, fleets and owner-operators have the lowest acquisition cost when choosing this option.

In the past, the predominant brake size on the steer axle of a standard three-axle truck tractor was a 15x4 inch drum brake. In the new stopping-distance environment, the use of that size is diminishing and 16½x5 inches is becoming the most commonly specified steer-axle drum brake.
Air Disc Brakes Optimize Vehicle Safety

The spirit of the new stopping distance law is to make heavy trucks safer. Converting to larger, more powerful drum brakes will enable fleets and owner-operators to meet the minimum requirement. But for the greatest stopping power in all conditions, and optimized vehicle safety, the clear choice is air disc brakes.

When compared to drum brakes, air disc brakes offer a number of advantages, including:

- **No exaggeration of friction coefficient differences.** This results in improved side-to-side consistency between left and right brakes.

- **Reduced fade.** Consistent contact between the friction surfaces remains, even in the new lining condition and as the disc heats up and undergoes radial expansion.

- **High thermal load.** Heat dissipation is efficient for internally vented brake discs. As such, it is possible to maintain high braking performance, even in demanding conditions.

- **Minimal and consistent hysteresis.** This is due to the high efficiency of the actuating mechanism. Hysteresis is the lag in response between brake actuation and functioning.

- **Servicing ease when changing brake pads.** When compared to drum brakes, disc brakes require only 1/4 of the service time once wheels are removed.

The ability of air disc brakes to resist fade is particularly important. In the “Braking Solutions” section of this white paper, we discussed the concept of thermal capacity, which is the amount of heat the braking system can retain. The thermal capacity of drum brakes is a fraction of the thermal capacity of air disc brakes. The hotter a drum brake gets, the less efficient it is, and the more it can exhibit brake fade. Air disc brakes, on the other hand, are much less prone to brake fade.
Where this capability is most critical is when a truck is driving down a mountain. To maintain a safe speed, a driver must use repetitive braking applications, or “snubs.” Snubs slow the vehicle speed, but don’t allow the system time to cool down and recover. Instead, it gets hotter and hotter. A worst-case scenario is that when the brakes are the hottest, the truck is forced to make a panic stop. The performance of disc brakes is far superior to that of drum brakes in this circumstance, because thermal capacity for air disc brakes is greater. Larger, high performance drum brakes exhibit less fade than ordinary drum brakes, but both fall short of air disc brake performance levels.

The new NHTSA rule considers a truck’s ability to stop one time on level ground in moderate ambient temperature. Panic stop braking near the end of a downhill run, while beyond the realm of the stopping distance rule, is a real possibility on the road.

**The Performance Metrics Chart**

When considering braking solutions, fleets and owner-operators can use a performance metric chart that compares brake options in the categories of torque, weight, fade, and cost to help in the selection.

Below is a chart comparing 15x4 inch drum brakes, conventional 16½x5 inch drum brakes, High Performance 16½x5 inch drum brakes and air disc brakes. As discussed earlier in this section, the 15x4 inch drum brake is being used increasingly less because larger brakes are better able to meet the new stopping distance rule.

<table>
<thead>
<tr>
<th>Brake Type</th>
<th>Torque</th>
<th>Weight</th>
<th>Fade</th>
<th>Acquisition Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 x 4 inch drum</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>16½ x 5 inch drum</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>High Performance 16½ x 5 inch drum</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Air Disc</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

*Source: Bendix Spicer Foundation Brake*
A vehicle delivering fuel through the mountains of western Pennsylvania will have different braking needs than one transporting furniture from Detroit to Des Moines. Understanding the performance categories and costs – and the trade-offs involved – will allow fleets and owner-operators to choose the best braking system for their operation.

**The Role of Independent Wheel Control**

Testing has shown that more sophisticated electronic stability control systems, while making vehicles safer from a stability standpoint, also maximize stopping capability. Independent wheel control – a characteristic of stability systems deploying six sensors and six modulators – enhances a vehicle’s ability to meet the stopping distance requirements.

In the past, a basic four-sensor, four-modulator antilock braking system (ABS), in which one modulator controls more than one wheel, was usually sufficient to help the braking system meet the stopping distance standard. For trucks close to or barely meeting the new requirement, the more sophisticated control option may be beneficial.

**Effect of Speeds above 60 mph**

The amended FMVSS No. 121 sets stopping distance standards for commercial vehicles traveling 60 mph. In practice, many trucks operate faster than that, legally or not.

As discussed in the “Braking Solutions” section, kinetic energy is defined by the equation \( KE = \frac{1}{2} MV^2 \) – in which \( KE \) is kinetic energy, \( M \) is mass or load, and \( V \) is velocity or speed. Brake demand rises exponentially with vehicle speed. Stopping a truck going 70 mph requires far more braking power than one traveling 60 mph.

Air disc brakes outperform drum brakes at 60 mph. As speed is increased, disc brakes perform increasingly better compared with drum brakes. Fleets and owner-operators are advised to consider that difference when choosing brake systems.
Solutions for Phase Two of the Final Rule

Using advancements developed to address phase one, including the expanded use of air disc brakes, as well as drum brakes featuring higher performing friction and other innovations, brake manufacturers are prepared to meet the phase two launch.

In general, solutions for phase two emphasize a further increase in air disc brake usage – in some applications, air disc brakes will be required – and drum brakes designed with additional technologies.

Phase two affects heavier vehicles and those with a wider variety of axle arrangements, requiring friction materials that provide more brake torque to both steer and drive axle brakes. For example, heavier vehicles with short wheelbases need more capable brakes on both the steer and driving axles. As a result, new brake offerings include larger chambers and higher performance friction material on drive axles.
The final rule is an important step toward balancing stopping performance between the many vehicle types that share America’s roadways. The commercial vehicle industry has been preparing for years for reduced stopping distances.

**Impact on OEMs and the Vehicles They Produce**

OEM truck builders have approached the 30 percent reduction in stopping distance in their own ways. The regulation did not mandate one type of brake, so OEMs had the option to choose which solutions would be best for them and their customers.

Vehicle manufacturers also determined what, if any, vehicle modifications to axles, suspension, and other components were necessary to accommodate higher brake torques associated with shorter stopping distance.

Some OEMs primarily upgraded steer axle brakes. Others also made changes to drive axle brakes. One truck builder, Peterbilt Motors Company, announced in June 2011 that Bendix® ADB22X™ air disc brakes had become standard position on the steer axle of all Peterbilt® Class 8 truck tractors.
Peterbilt became the first major heavy truck OEM to offer air disc brakes as standard across its Class 8 product line. A year earlier, Peterbilt made the ADB22X standard equipment on the steer axle of its flagship Model 587.

**Effect on Fleets and Owner-Operators**

Fleets and owner-operators, meanwhile, continue to weigh a variety of factors – such as upfront costs, maintenance intervals, replacement parts, and driver retention – and have different philosophies as to how to spec new rigs to adhere to the regulation.

Because NHTSA is not advocating a specific technology, fleets and owner-operators are able to make foundation brake decisions based on their own needs and preferences. The key is that they still have foundation brake choices.

The mandate has spurred fleets and owner-operators to significantly increase their focus on braking systems. This heightened attention has resulted in a major upsurge in air disc brake sales, as noted earlier in this paper. The professionals specifying brakes are evaluating air disc brakes and, in increasing numbers, are concluding that they are a solid choice.
Fleets and owner-operators have better brakes as a result of the NHTSA rule, but the need for robust maintenance practices on brakes does not change. Brake inspections and brake jobs are still required at appropriate times.

**Impact on Brake Manufacturers**

To meet the reduced stopping distance mandate, leading brake system manufacturers are moving beyond simply providing more stopping power. They are also focused on ensuring that their improved braking systems continue to address day-to-day drivability issues for impacted vehicles. Therefore, brake manufacturers continue to work closely with the industry – including vehicle OEMs, fleets, and end-users – to offer systems that meet this important goal.

**Value Proposition of Higher-Performing Brakes**

Some in the industry have the misperception that solutions to meet the new stopping distance standards are prohibitively expensive. In reality, the added cost of larger, high performance drum brakes will total less than $100 per vehicle. That nominal increase brings big value:

- **Improved safety and less property damage.** As noted earlier in this paper, NHTSA estimates that by implementing the improved braking technologies that meet the new requirements, approximately 227 lives will be saved and 300 serious injuries will be prevented annually. An annual savings of more than $169 million in property damage from crashes is anticipated.

- **Longer life.** Air disc brakes are the gold standard for longevity in brakes. In the past, they lasted about twice as long as drum brakes. But the larger, high-performance drum brakes have closed the gap, wearing as well or even better than disc brakes.
• **Life-cycle costs decrease because wear is balanced across the whole vehicle.** Upgraded steer-axle brakes are approaching the performance capability of drive-axle brakes. Because the steer-axle brakes are doing more work, braking action is distributed over more axles, bringing the opportunity for longer system life.
What the Mandate Means for the Aftermarket

The new and emerging braking technologies can be used by fleets and owner-operators wishing to upgrade their vehicles through retrofitting. Foundation brakes today are able to accommodate the dimension of larger drum brakes or disc brakes and ensure the proper fit within the existing wheel-end envelope.

Choice of replacement parts also remains a critical consideration in the industry. To have the safest trucks on the road that are always up to OEM standards, fleets and owner-operators should choose original equipment replacement parts. From a safety perspective, the new NHTSA mandate makes this practice all the more important. Using inferior replacement parts compromises performance.

Owner-operators and fleet decision makers are responsible for their vehicles from the front bumper to the taillights. They can’t be experts on every part, and sometimes they incorrectly assume that the replacements products they buy from their suppliers are compliant with the standards for new vehicles. For aftermarket parts, however, compliance is not a legal requirement. While not legally required, original equipment replacements parts, or those specified by the OE, offer fleets and owner-operators maximum safety, performance, and longevity.

Replacing High Performance Friction with Like Friction Is Essential

Choosing the proper replacement brake linings is especially critical. As discussed, to meet the new reduced stopping distance standards, brake manufacturers have responded with high performance foundation drum brake systems that factor in a wide range of variables, such as axle load rating, wheelbase, and tire size.

The high performance linings engineered for these systems feature significantly higher stopping power, and less fade. They also maintain their performance levels much more effectively when subjected to the temperature increases that occur during demanding brake usage, like carrying heavy loads, frequent stops, and operating in mountainous regions.

Despite the fact that fleets and drivers have added new high performance drum brakes to their vehicles, many remain unaware that the routine maintenance decision for specifying replacement friction can negate the technological advancements of the brakes – and potentially compromise safety.
Relining today’s high performance drum brakes with typical aftermarket friction, and not the linings specified by the OEM, can significantly reduce a vehicle’s stopping capability and may lead to longer stopping distances.

Low-cost aftermarket friction is not engineered to the same standard and thus is not suitable for consideration as original equipment or replacement friction on heavy trucks and tractors built after August 2011.

**Demystifying FMVSS 121 Testing**

Today there remains significant, widespread confusion about friction replacement related to the FMVSS 121 dynamometer test procedure, which is outdated in the new reduced stopping distance environment.

Unfortunately, passing this test is still considered by many to be a seal of approval for replacement linings. Results of the test are often viewed as an indicator that a brake lining will supply the torque output needed to stop a vehicle within the new standards, but this is not necessarily the case.

Bendix compared the stopping distance performance of various linings on high performance drum brakes. The company measured the 60 mph stopping distance of a mandate-compliant vehicle with OEM brakes and high performance linings. Bendix then replaced the friction with multiple non-high performance original equipment and aftermarket materials that had passed the FMVSS 121 dyno test, but were not suitable for mandate compliance.

With nothing else changed, the vehicle’s stopping distance increased from 215 feet using the high performance friction to 311 feet with the worst-performing aftermarket replacement friction – a stunning 45 percent decrease in performance. That 96-foot difference in stopping distance – a total of five passenger car lengths – is a stark illustration of the roadway safety at stake.
The new NHTSA stopping distance legislation will save lives on our nation’s highways. NHTSA’s standards – phase one of which took effect Aug. 1, 2011, and phase two on Aug. 1, 2013 – reduce the disparity in braking performance between passenger cars and heavy trucks.

By shortening stopping distances for heavy trucks by 30 percent, fewer collisions – and fewer severe collisions – will occur in instances of panic stop braking. As a result, NHTSA estimates that once all heavy trucks on the road meet the new requirements, approximately 227 lives will be saved and 300 serious injuries will be prevented annually. The agency also estimates an annual savings of more than $169 million in property damage, which alone is expected to exceed the total cost of the rule.

The federal mandate is part of an industry trend toward stronger regulation and enforcement of truck braking systems. Other examples are Compliance, Safety, Accountability (CSA), a nationwide vehicle-safety initiative that began in 2010, and the move by some states to reduce the amount of copper allowed in brake lining materials.

For more than five years, the commercial vehicle industry has been preparing for shorter stopping distances. A variety of solutions are available to meet the requirements. The solution that will be chosen most often by fleets and owner-operators is larger and more powerful drum brakes on the steer axle – a solution that will add less than $100 to the price of each vehicle.

At the same time, increasing numbers of fleets and owner-operators are specifying air disc brakes, determining that the superior performance and longevity offered by disc brakes are worth the added investment.
This white paper was researched and authored by Gary Ganaway and Aaron Schwass, trucking industry veterans with extensive knowledge of and expertise in commercial vehicle braking systems.

Gary Ganaway serves the organization as director, marketing & global customer solutions. In this post Gary leads the activities associated with the global growth and product planning for the wheel-end business, along with continued leadership in the marketing activities associated with the wheel-end product lines. A 20-year, highly accomplished commercial vehicle industry veteran, Gary joined Bendix Spicer Foundation Brake in November 2009. Gary’s industry involvement includes membership in SAE and his most recent leadership role as a past chair of the Air Disc Brake Taskforce for the Technology & Maintenance Council (TMC). He holds a Bachelor of Science degree in mechanical engineering from Kettering University, Flint, Mich.; a certificate in marketing technology products from Caltech in Pasadena, Calif.; and a Master of Business Administration degree from the University of Michigan, Ann Arbor.

Aaron Schwass was named Vice President & General Manager, BSFB in January 2012, assuming executive oversight for the BSFB drum brake and disc brake product lines, the Kalamazoo Engineering/R&D center, and BSFB manufacturing operations in Bowling Green. In July 2011 he was appointed as one of two interim general managers for the business.

A talented executive with wide-ranging industry experience, Aaron’s career at Bendix and Honeywell/AlliedSignal (owners of Bendix prior to January 2002), spans 16 years. He most recently held the post of director – Foundation Brakes Business from March 2009. Aaron joined Bendix Spicer Foundation Brake in 2008 after 12 years with Bendix Commercial Vehicle Systems LLC. During his tenure with Bendix, Aaron has held numerous key leadership roles including Acuña, Mexico Plant Manager; Manager – Bendix Product Development Integration; Interim Director – Operations; and Director – Supply Base Management, a role in which he served since 2004.

Aaron holds a Bachelor of Science degree in Industrial and Operations Engineering from the University of Michigan in Ann Arbor and a Masters of Business Administration from the University of Texas in Austin.

Additional sources used in this white paper include the National Highway Traffic Administration and the Federal Motor Carrier Safety Administration.