


THE FEDERAL REDUCED STOPPING DISTANCE MANDATE: IMPACT AND SOLUTIONS



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IMPORTANT TERMS

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.

EXECUTIVE SUMMARY

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 phase one. Brake system testing and validation is ongoing to enable solutions to meet phase two's requirements.

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In this paper, we will discuss the specifics of the new 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.

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 significant 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.

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As described by the FMCSA, CSA introduces 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 Rhode Island and New York.

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.

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 Spicer Foundation Brake (BSFB) 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.

Industry wide, air disc brakes capture only a 6 percent market share, with drum brakes encompassing 94 percent. Their acceptance is clearly growing, however, as evidenced by the new production line at BSFB. The industry is increasingly demanding air disc brakes and the higher performance and safety, as well as less frequent maintenance they require.

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UNDERSTANDING THE NEW STOPPING DISTANCE REQUIREMENTS

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.

The new rule is being implemented in two phases and affects nearly all 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:

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

Source: National Highway Traffic Safety Administration

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.

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.”

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, 3,380 people were killed in crashes involving large trucks in 2009, the most recent year for which statistics are available. During the prior year, 4,229 people died in truck crashes. The decline from 2008 to 2009 is attributable, in part, to fewer trucks on the road and reduced freight shipments, both a result of the recession.

In 2009, 74,000 people were injured in large-truck accidents; in 2008, 90,000 people were injured. Of the 2008 crashes, 16 percent of those killed and 26 percent of those injured were occupants of (please verify that the 26% of all injured were occupants of large trucks or 26% of crashes involved) large trucks.

Deaths and Injuries Resulting from Collisions Involving Large Commercial Vehicles		
Year	Deaths	Injuries
2008	4,229	90,000
2009	3,380	74,000

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 will be able to avert many collisions that, in the past, were often unavoidable.

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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.

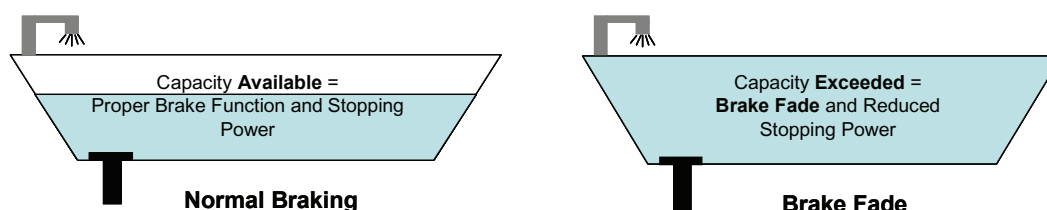
Another concept to understand is the energy equation. The role of the foundation brake is to reduce the velocity of the vehicle. The heavier the load and higher the speed, the greater the kinetic energy and, subsequently, the greater the braking demand is to achieve this reduced velocity.

Kinetic energy is defined by the equation: $KE = \frac{1}{2}MV^2$. 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.



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.

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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.

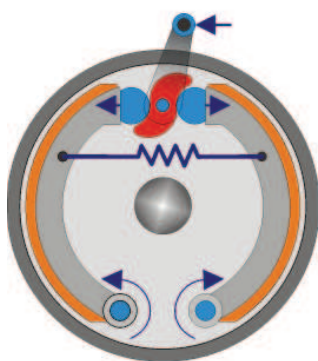
Going back once again to the bathtub illustration, if the drain is unable to keep pace with the rate at which water is being added, the tub will overflow. Overflowing water means that the capacity of the system has been exceeded. This is parallel to the braking phenomena known as **fade**. Fade is the 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 as 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.



Bendix® S-Cam Drum Brake



S-Cam

Source: Bendix Spicer Foundation Brake



Bendix® Versajust™ Slack Adjuster

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 not be prone to noise.

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.



Bendix® Splined Disc Rotor

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 between less than 250,000 miles for a typical linehaul application. Today, it is very common of linehaul tractors to go 600,000 miles before the linings wears out. Air disc brakes lining are performing even better and it is common for ADB equipped linehaul tractors to go between 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.
- **Additional lining** for longer life.

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MEETING THE REDUCED STOPPING DISTANCE MANDATE

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.

Top-of-Mind Considerations 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.

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 tridemms (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.

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).

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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.

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.

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, 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.

Brake Type	Torque	Weight	Fade	Acquisition Cost
15 x 4 inch drum	Low	Low	High	Low
16½ x 5 inch drum	Medium	Medium	Medium	Medium
High Performance 16½ x 5 inch drum	High	Medium	Low	Medium
Air Disc	High	Medium	Low	High

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 tradeoffs 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.

Testing has shown that more sophisticated electronic stability control systems, while making vehicles safer from a stability standpoint, also maximize stopping capability.

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.

Air disc brakes outperform drum brakes at 60 mph. As speed is increased, disc brakes perform increasingly better compared with drum brakes.

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.

WHAT THE MANDATE MEANS FOR THE INDUSTRY

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 are approaching the 30 percent reduction in stopping distance in their own ways. The regulation did not mandate one type of brake, so OEMs have the option to choose which solutions are best for them and their customers.

Even so, one factor unites OEMs: The new mandate requires them to assess, make choices, and strategically change their operations. They must consider the potential impact on everything from their production lines, to vehicle weight and complexity, to part numbers in their system. They must complete the hard work of compliance requirements, testing, and evaluation.

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

Some OEMs are primarily upgrading steer-axle brakes. Others are also making changes to drive-axle brakes. One truck builder, Peterbilt® Motors Company, announced in June 2011 that Bendix® ADB22X™ air disc brakes were chosen for standard position on the steer axle of all Peterbilt Class 8 truck models.

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



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, are weighing a variety of factors – such as upfront cost, maintenance intervals, replacement parts, driver retention, and vehicle applications – and have different philosophies as to how they’re going 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 maintain foundation brake choices.

The mandate has spurred fleets and owner-operators to significantly increase their focus on braking systems. One result of this heightened attention is the major upsurge in air disc brake sales noted earlier in this paper. The people specifying brakes are carefully evaluating disc brakes and concluding that they are a solid choice.

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 maintain foundation brake choices.

Fleets and owner-operators will 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 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 replacement 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 replacement parts offer fleets and owner-operators maximum safety, performance, and longevity.

Choosing original equipment brake linings is especially critical. Bendix, for instance, is using a combination lining that up until now wasn't available in the industry. Replacing it with a non-combination replacement lining will compromise brake performance.

Fleets and owner-operators will 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.

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.

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.

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CONCLUSION

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, 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 (CAS), 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.

ABOUT THE AUTHORS

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 will lead the activities associated with the global growth and product offerings for the wheel end business, along with continued leadership in the marketing activities associated with the wheel end product lines. A 20-year commercial vehicle industry veteran with substantial accomplishments in both the passenger car and commercial vehicle segments, he is highly effective at technology deployment, strategy development, marketing and product portfolio management, and product management. Gary joined Bendix Spicer Foundation Brake in November 2009 after he held the role of senior director business and product strategy – light vehicles at ArvinMeritor. 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.



Gary Ganaway, Director – Marketing & Global Customer Solutions at Bendix Spicer Foundation Brake LLC

Aaron Schwass serves as vice president and general manager at Bendix Spicer Foundation Brake. In this role, Aaron oversees drum and disc brake operations, engineering operations in Kalamazoo, Mich., and BSFB’s manufacturing facility in Bowling Green, Ky. Prior to joining BSFB in 2007, Aaron spent 12 years in key leadership positions at Bendix Commercial Vehicle Systems. His experience includes serving as plant manager in Acuña, Mexico, manager of Bendix product development integration, director of supply base management, and interim director of operations. He earned a bachelor’s degree in industrial and operations engineering from the University of Michigan, in Ann Arbor, and a master’s of business administration from the University of Texas, in Austin. He will also serve as BSFB’s acting product line director for air disc brakes until that position is filled.



Aaron Schwass, Vice President & General Manager at Bendix Spicer Foundation Brake LLC

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



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