

**The Case for Electronic Brake Monitoring in Medium - Heavy
Commercial Vehicle Air Brake Applications**



I. Commercial Medium – Heavy Vehicle Air Brakes and Safety

Most of today's large over-the-road commercial vehicles (trucks, trailers, buses, and vocational vehicles) utilize air brake systems to provide vehicle braking, as opposed to passenger cars which utilize hydraulic braking. Air brake systems have proven to be quite capable in providing the brake forces required, in order to safely decelerate and stop large vehicles in both on road and off road applications. That being said, there are unique maintenance and inspection requirements for air brake systems that must be regularly and properly completed, in order to maintain the vehicles brake system integrity and overall braking capability.

Industry and the government have long recognized the need for commercial vehicle air brake maintenance and inspections. Vehicle owners are required (per CDL requirements) to conduct a "pre-trip" inspection of the vehicles brakes before daily operation. In addition, the government (DOT) conducts random road side inspections of vehicles on the nation's highways, and checks for proper brake system maintenance and operation.

While this approach sounds logical and effective, in reality proper brake maintenance and adjustment is a common and recurring issue in the commercial vehicle industry. There are several reasons that contribute to this problem as acknowledged by government reports and inspection data:

- Very few fleet operators conduct a pre-trip brake inspection of their vehicle(s) before placing them into daily service. The reasons for this are, that the inspection takes time, that the procedure requires physically inspecting the vehicles brakes by crawling under the vehicle, and that a pre-trip brake inspection typically requires two persons in order to be done properly.
- Very few vehicles are actually inspected at road-side inspection stations, due to the limited number of inspection stations in operation, and the limited qualified personnel available to check for proper vehicle air brake operation.
- Air disc brakes (recently introduced to the North American market), are virtually impossible to visually inspect for proper operation.
- Improper air brake system maintenance due to a lack of qualified mechanics and a general need to reduce operating and maintenance costs wherever possible.

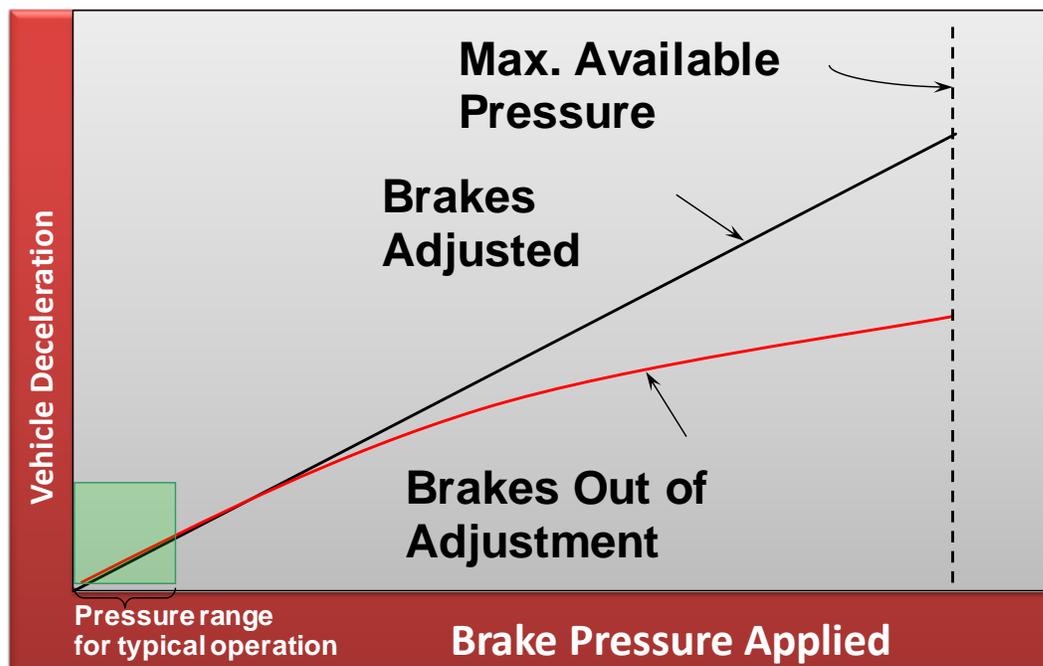
II. The Significance of Proper Commercial Vehicle Air Brake Operation and Adjustment

It is well known that proper commercial vehicle air brake operation and adjustment is essential in order to ensure full vehicle braking capability. If for example, the vehicle is equipped with six brakes (wheel ends), and if some or all of these brakes are inoperative (or out-of-adjustment) then vehicle stopping distances increase based on the quantity and severity of the inoperative or out-of-adjustment brake conditions.

A unique feature of commercial air brake systems is that there is no direct "feedback" from the driver's air brake pedal, and the overall operation of the air brakes on a vehicle. This is because, unlike automotive hydraulic brakes, there is no direct mechanical link between the vehicle air brake pedal and the air brakes at each wheel. Thus, the feedback the driver receives from the brake pedal on a commercial air brake vehicle is the same no matter if the brakes are properly operating, or if they happen to have a serious mechanical issue.

In addition, since most daily brake applications on a commercial vehicle occur at very low brake pressures, the driver typically has no indication that his brakes are inoperative or out-of-adjustment until they are needed in panic situation. During a panic stop, suddenly the vehicle brake system is asked to respond, and only at this time does it become evident that some or all of the brakes on the vehicle are out-of-adjustment or defective.

If the vehicles brakes are properly operating, there should be a fairly linear relationship between brake force being applied by the driver and the subsequent vehicle deceleration. If the vehicles brakes are not fully operative or out-of-adjustment, then this relationship is not linear and stopping distances can radically increase (especially in a panic stop situation as noted above). This effect is shown in the graph below. This condition can result in vehicle instability and excessive stopping distances leading to increased risks and the subsequent severity of a collision.



III. Industry Data Concerning Commercial Vehicle Air Brake Operation and Adjustment

Government inspection data (gathered from random road-side inspections), has repeatedly highlighted the need for better maintenance and monitoring of brake operation and adjustment on commercial air brake equipped vehicles. A recent CVSA road check program was conducted in June 2013, and the inspection and out-of-service (OOS) data is quite revealing.

- 73,023 truck and bus inspections were conducted (including 1,471 motor coaches)
- 47,771 Level 1 inspections (which includes brakes) were conducted
- 24.1% of the vehicles (of the 47,771 inspected) were found with OOS violations
- Brakes routinely stood out in the mix of OOS violations issued
- 49.6% of vehicle OOS violations were related to brake adjustment
- 287 inspections were conducted with Performance Based Brake Testers (PBBT)

- 12.5% vehicles were found (of the 287 inspected) with overall brake efficiency below the minimum required by US regulation and the North American Standard OOS criteria. As found per PBBT testing of each vehicle.

IV. The Scientific Link Between Commercial Vehicle Brake Defects and Accident Causation

Scientific study, as well as forensic accident investigations by NTSB (National Transportation Safety Board), has well documented the link between vehicle brake defects and accident causation and severity. A recent study by the University of Michigan Transportation Research Institute (UMTRI), scientifically analyzed data from of The *Large Truck Crash Causation Study* (LTCCS) conducted by FMCSA and NHTSA during 2001 to 2003. This data set is the largest and most well-known study conducted involving commercial vehicle accidents and their causation. By carefully analyzing the data from this study, UMTRI proved that the only vehicle mechanical defect that can be directly linked to accident causation is brake defects. Highlights from this UMTRI study revealed:

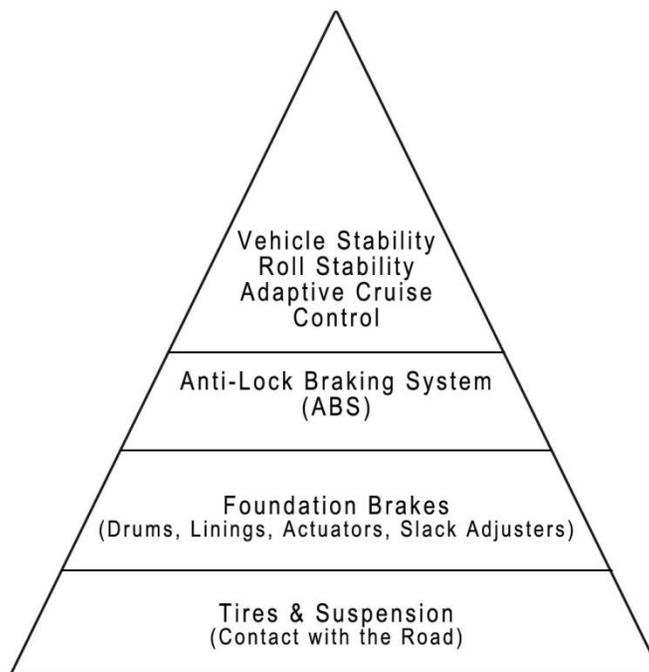
- The sample size was 963 crashes involving heavy trucks
- Actual physical inspections were performed on 1001 trucks in this study
- Brake adjustment data was available on 826 trucks
- 33% of the trucks involved had at least one brake CVSA OOS condition
- 20% of the trucks involved would have been put out of service due to 20% or more of the vehicles brakes being defective
- Brake violations were the highest among all mechanical systems inspected
- *Of all mechanical defects, only brake adjustment was found to have a statistically significant relationship to accident causation*
- No other mechanical defect was found to be statistically significant
- A vehicle is 1.8X more likely to be the striking vehicle in a brake related collision if its brakes are out of adjustment. This likelihood increases to 3.5X more likely if the vehicle is loaded.

In addition, the NTSB has recently conducted two accident investigations where there was loss of life, and found in both cases that defective brakes were a causal factor in the likelihood and severity of the accidents. The first case involved a collision between a Tractor-Trailer and an Amtrak passenger train in Miriam, Nevada in 2011 and the second case involved a collision between a Truck and School Bus in Chesterfield, NJ in 2012. As a result of these two accident investigations, NTSB has issued two recommendations to National Highway Transportation Safety Administration (NHTSA) concerning vehicle braking safety technology.

- **H-12-58:** Develop minimum performance standards for onboard brake stroke monitoring systems for all commercial vehicles
- **H-12-59:** Once the performance standards in Safety Recommendation H-12-58 have been developed; require that all newly manufactured air-brake commercial vehicles be equipped with onboard brake stroke monitoring systems.

V. The Relationship Between Commercial Vehicle Foundation Brake Operation / Adjustment and other Advanced Safety Technologies

Advanced Safety Technologies such as ABS, Collision Avoidance, Roll Stability, and Vehicle Stability are all examples of new technologies that increase vehicle safety, and can ultimately reduce collisions and their severity. That being said, it is often overlooked, that these advanced safety technologies ultimately rely on properly adjusted and operating foundation brakes in order to be effective. The “Safety Technology Pyramid” shown below graphically illustrates the relationships and dependencies of these various safety technologies.

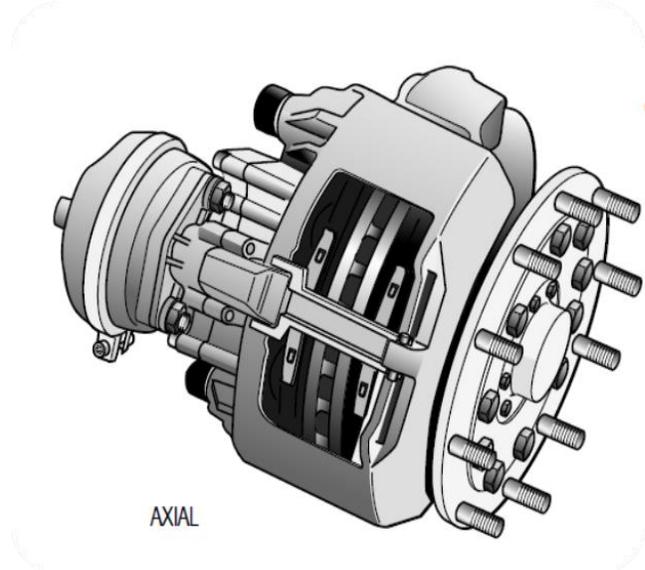
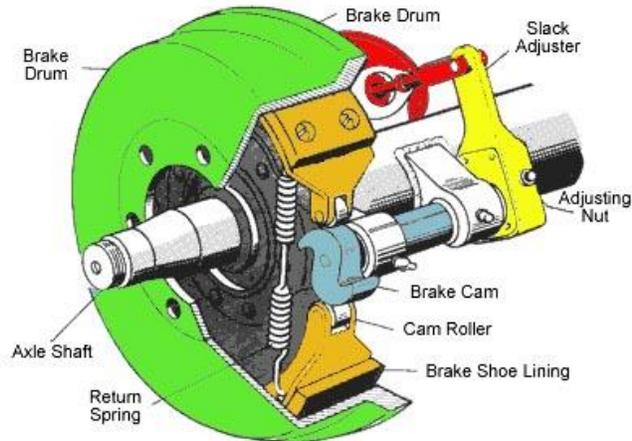


Safety Technology Pyramid

It can be seen from the Safety Technology Pyramid and the subsequent interaction of the various safety technologies, that all depend upon proper brake adjustment in order to be effective. For example, the ABS system cannot intervene if a wheel is unable to achieve lock-up, and the Vehicle Stability System is unable to properly intervene if the brakes cannot fully or properly apply during a vehicle maneuver. This makes it critical that air brake operation is closely monitored, and foundation brake issues corrected, if these dependent technologies are to perform at their full potential. Constant monitoring of air brakes can provide early warning of pending brake system issues, thus allowing foundation brake problems to be addressed before the foundation brake system is called upon to intervene by other advanced safety technologies in a dangerous driving situation.

VI. A Special Note Concerning Commercial Vehicle Air Disc Brakes

A recent trend in the industry is to specify and build newer commercial vehicles with air disc brakes. Commercial air disc brakes are quite different from the more well-known s-cam (or drum brakes) that have been quite common in North America for many years. Air disc brakes, while offering advantages to the fleet operator, also present unique difficulties and challenges when it comes to inspection and maintenance of these brake systems. Below are two illustrations showing a typical s-cam (drum), and a typical air disc application for modern commercial vehicles.



On the left you see a typical s-cam (drum) application that includes a brake chamber with an exposed pushrod, an automatic brake adjuster (ABA), a s-cam tube and bushings, cam rollers, linings and a drum. In this application, all parts are basically “exposed” which allows the fleet operator to visually check and inspect s-cam equipped vehicles using standard industry inspection criteria as defined by CDL requirements. Major component malfunctions can be checked and inspected visually by placing the vehicle on a lift and actuating the brakes, or through the use of electronic brake monitoring. CVSA has standard procedures for checking brake function and stroke for these applications.

On the right you see a typical air disc application that includes a brake chamber with a fully enclosed pushrod, a brake caliper with an internal adjuster mechanism, a rotor, and brake pads. This type of braking system poses unique challenges to the fleet in terms of visual brake inspections. There is no exposed pushrod in order to check chamber stroke, and the internal adjuster mechanism (designed to keep pad clearance constant like an ABA on s-cam systems), is fully enclosed, sealed, and not possible to visually inspect. In addition, the pads and outboard rotor face are nearly hidden from view making it difficult to check pads or rotor conditions visually, without wheel removal for subsequent detailed inspections. The industry has long known that a visual inspection of air disc brakes for proper operation is impractical, and this has been acknowledged by CVSA as a serious concern. The most common visually inspection method employed is simply to “check the rotor for rust” which would indicate the brake is inoperative (*can require wheel removal*). **Thus with air disc brakes the fleet operator does not truly know with a visual inspection any of the following:**

- The brake actuator (or brake chamber) is operative
- The caliper internal adjuster is operative and maintaining pad clearance under all conditions
- The wheel end is providing full braking, partial braking, or no braking
- The brake actuator (or brake chamber) stroke is within acceptable operating limits
- The brake is lightly dragging (warning of other serious problems)

VII. The Need for Commercial Vehicle Electronic Brake Monitoring

The vehicles in a commercial fleet are valuable and costly assets, not to mention the associated liability if a fleet transports personnel or hazardous and high dollar cargo as a daily part of its operations. The government and scientific data is clear. There is a direct proven relationship between commercial vehicle air brake operation and the inherent risk or severity of being involved in an accident. Now add in the complexity of being able to properly and fully visually inspect and maintain a vehicles air brake system and a strong case can be made for upfront investment in electronic brake monitoring. The cost of one vehicle total loss, or associated liability costs of a vehicle collision, can quickly justify the need for the technology. In addition electronic brake monitoring can significantly reduce maintenance costs, and identify brake problems before they become more extensive and costly. Electronic brake monitoring can accurately find and identify the following typical air brake system problems:

- Air brake system electrical control and air valve failures (including ice in the air system)
- Broken air lines and hoses
- Defective brake actuators (brake chambers)
- Defective automatic brake adjusters (ABA's)
- Defective caliper operation (internal adjuster mechanism)
- Defective service or parking brake operation
- Low caliper pad clearance resulting in light drag and excessive pad wear
- Dragging brakes which can result in a thermal event
- Out of adjustment brakes (over-stroke) which leads to reduced braking performance
- Missing brake pads or rotor sections
- Broken s-cam tubes, worn pads and brake drums, and other mechanical issues
- Non-functioning brakes (wheel ends where no braking is being performed)

VIII. The Mature Technology – Electronic Brake Monitoring

Electronic Brake Monitoring for commercial vehicle applications has been in OEM production since 2001. Systems have been successfully deployed on Transit buses, Tractors, and Trailers over that period of time. To date, there are approximately 8,000 commercial Electronic Brake Monitoring systems deployed across the United States with more being added every year. MGM Brakes has worked extensively with the Transit industry in deploying a robust technology for both s-cam and now air disc equipped commercial vehicles. The technology has proven capable of withstanding the rigors of an urban transit environment (some of the most severe applications in the industry). As a result, all major Transit Bus OEM's install the technology as an option. In addition, over-the-road fleets have also installed Electronic Brake Monitoring with success, with the technology proven to be able to withstand the rigors of over-the-road applications

As an additional point of clarification, it should also be noted, that the current generation of Electronic Brake Monitoring technology fully supports tractor-trailer installations with the trailer brake status being readily displayed in the cab of the vehicle. There is no need for the driver to exit the vehicle in order to know the status of the brakes on both the tractor and trailer while in operation.

IX. Electronic Brake Monitoring Technology Additional Capabilities

Electronic brake monitoring (when integrated with the vehicle control systems), can offer many other additional capabilities. This is accomplished via the vehicle I/O system or via the vehicle J-1939 network:

Dragging Brake Intervention System: If MGM's electronic brake monitoring system detects a continuous and dangerous dragging brake condition on the vehicle, the following safety sequence is automatically initiated to protect the vehicle and occupants:

- After 30 seconds of continuous driving, the warning light will illuminate (or the intelligent display will message the driver) indicating a brake drag is present
- After 60 seconds of continuous driving, the warning light will begin to flash (or the intelligent display will flash the message to the driver) indicating a brake drag is present.
- After 90 seconds of continuous driving, an audible alarm will sound and the vehicle four way flashers will automatically engage.
- After 120 seconds of continuous driving, the engine will de-rate to a top speed of 15 MPH allowing the driver to safely move the vehicle out of traffic and to a safe parking position
- Once the vehicle is parked, the interlocks will automatically engage and the vehicle will go into lock down awaiting a maintenance technician service call.

Other possible advantages or uses of electronic brake monitoring also include:

- Automating the pre-trip inspection procedure
- Capturing brake application pressure data during panic stops
- Using the electronic brake monitoring logging feature during accident investigations

X. Commercial Vehicle Electronic Brake Monitoring Closing Comments

Our goal as a society should be to keep everyone safe while traveling on the nation's roads. While significant progress has been made, much room for improvement remains. Technology, when properly adopted, can save lives and make our highways safer for all involved. The data is clear, and the technology exists to address this industry issue. In summary:

- Out-of- adjustment brakes continue to be found in significant numbers in roadside inspections despite the prevalence of automatic slack adjusters and fleet preventative maintenance efforts.
- An analysis of the Large Truck Crash Causation Study database by UMTRI indicates that one-third of the trucks involved in the fatal accidents had at least one brake out of adjustment, and that brake adjustment was the only mechanical defect that was found to have a statistically significant relationship to accident causation.
- Advanced crash avoidance technologies such as ESC, RSC, adaptive cruise control and automatic braking will not perform properly if the foundation brakes are not properly operating and adjusted.

- Modern air disc brakes, unlike S-cam (drum) brakes are fully enclosed and their proper function cannot be determined with a simple visual inspection.
- Electronic brake monitoring is commercially available for both S-cam (drum) and air-disc foundation brakes, and these systems incorporate multiplexing technology for vehicle-to-vehicle communication so that drivers have real time access to trailer brake status.
- Electronic brake monitoring is a mature technology with over 8000 systems in use, primarily in public transit, one of the most demanding vocations for braking components.
- Electronic brake monitoring is not only capable of detecting brakes out of adjustment, but also inoperative brakes, dragging brakes, and broken springs in parking and emergency brakes.

If you have questions regarding this whitepaper, or would like further information on this topic please contact:

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