Air Braked Commercial Motor Vehicles
Problems Solved, Problems Created

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Abstract

In 1992, after a two year study of over 1500 air braked vehicles and 15,000 foundation air brakes, the National Transportation Safety Board (NTSB) made several recommendations to improve commercial motor vehicle (CMV) air brake systems. They included:

- Mandatory brake adjustment indicators for air brake system vehicles manufactured after October 20, 1994. (49 CFR §571.121 S5.1.8 & 49 CFR §393.53)
- Mandatory self-adjusting brakes for air brake system vehicles manufactured after October 20, 1994. (49 CFR §571.121 S5.1.8 49 CFR §393.53)
- Antilock brake systems for truck tractors manufactured after March 1, 1997 (49 CFR §393.55 & 49 CFR §571.121 S5.1.6.1(b))
- Antilock brake systems for all other air braked vehicles (to include trucks, buses and semi trailers) manufactured after March 1, 1998 (49 CFR §393.55 & 49 CFR §571.121 S5.1.6.1(a))

These new regulations were promulgated under the Federal Motor Carrier Safety Regulations (FMCSR) Part 393 and the Federal Motor Vehicle Safety Standards (FMVSS) Part 571.

In addition, the report cautioned manufacturers to address issues related to the air brake imbalances caused, masked or aggravated by the use of front axle automatic limiting valves. It also cited the inherent natural brake imbalance that occurs when a vehicle with a heavy Gross Vehicle Weight Rating (GVWR) is operated empty. This had been recognized as a problem in controlling "bobtail" truck tractors when operating without semi trailers attached.

Improvements

These changes clearly should result in an improvement in highway safety. My own testing of CMVs manufactured after March 1, 1998 has convinced me of the clear superiority of the new technology when properly used and properly maintained.

My conversations with NTSB officials confirm an interest in conducting a follow up control study in an attempt to quantify if any significant improvement has been realized. NTSB has not scheduled a follow up study at this time.

At this time, the available data does not reflect a statistically significant improvement. CMV collision rates have not shown a significant improvement and "Out Of Service" (OOS) rates for mechanical defects have only dropped about 1% in the last four years (from 25% to 24%). The leading catagory for

a CMV to be declared OOS is still brake defects.

It is too early to draw any broad conclusions from this limited information, as normalizing statistical data would have to be considered to include but not limited too:

- Growth in the economy increasing CMV traffic.
- Improvement in inspection data allowing Motor Carrier Safety Assistance Program (MCSAP) to identify problem carriers for inspection.
- Evolving MCSAP inspection training and techniques revealing more brake defects.
- Actual percentage of "improved technology" CMVs in service.
- Training and understanding of the new technologies by the end users (drivers & maintenance personnel).
- Availability of test equipment to maintain the new technologies.

New Problems and Issues From New Technologies

This leads to the discussion of six specific areas that face the motor carrier industry, CMV collision investigator and MCSAP inspector.

- Mixing of combination vehicles equipped with ABS and without ABS.
- Self-adjusting brakes and Cam Shaft maintenance
- Worn camshafts & brake drum failure.
- Conversion of truck tractors to trucks.
- Testing and proper maintenance of ABS systems.
- Performance Based Brake Testers (PBBT)

Mixing of combination vehicles equipped with ABS and without ABS.

Operating non-ABS vehicles in combination with ABS equipped vehicles is neither illegal nor an uncommon practice in the last few years.

When the National Highway Traffic Safety Administration (NHTSA) mandated ABS brakes on air braked vehicles through the FMVSS, the first vehicles to be mandated were truck tractors (3/1/97).

This seemed the natural order as most of the testing and research had already been done on these units to improve stopping distances and reduce the effects that often lead to the jackknife of truck tractors and semi trailers.

The proportionate cost of approximately $1600 to $2500 was more easily absorbed on a new truck tractor, which can easily be three to six times the cost of a semi trailer.

Connecting an *ABS equipped semi trailer* to a non-ABS truck tractor has little effect in reducing the incidents of truck tractor jackknife but significantly reduce the danger of trailer wheel lockup and trailer swing out.

Connecting an *ABS equipped truck tractor* to a non-ABS equipped semi trailer greatly improves control of the truck tractor and reduces the probability of jackknife *but* significantly increases the risk of trailer swing out.

For the driver to optimize the effects of the ABS system during an emergency braking situation, he/she should "Stomp & Steer", making a full brake application and steering as needed. This will often result in a non-ABS semi trailer wheels to lock causing lateral instability and susceptibility to any lateral G forces. These will typically result in trailer swing out.

In dry pavement controlled tests from the 50 mph speed range, I have experienced as much as a five foot lateral swing of the semi trailer in relation to the path of travel of the truck tractor. The trailer swing can be of much greater magnitude on low friction surfaces.

The driver can reduce the effects of the trailer swing by releasing the brakes or "stab braking" (pumping the brakes). This will help control trailer swing but can interrupt the algorithms of the ABS and increase stopping distance.

This problem will be with us for many years for two primary reasons. When the regulation requiring ABS on air braked vehicles went into effect, truck tractors had a one-year head start over semi trailers (3/1/98).

This coincidentally occurred during a time of economic growth and when many motor carriers were expanding their fleets due to shippers needs, excellent lease deals and low interest rates. Many new truck tractors with ABS were purchased or leased along with non-ABS semi trailers.

The second reason is the motor carrier industry has always had many more semi trailers than power units. Some data suggests the ratio is as high as 10 to 1.

Large motor carriers find it much more profitable to spot empty semi trailers at or near shippers locations so drivers can "drop & hook". This is the practice where the shipper has the trailer loaded and ready for dispatch. The driver comes to the shipper, ***drops*** off an empty trailer or brings raw materials into the shipper. The driver then ***hooks*** up to the loaded trailer and can be back on the road in 15 – 30 minutes, maximizing use of the truck tractor and reducing unprofitable waiting time.

Even small motor carriers may have several different types of semi trailers, such as dry vans, refrigerated vans and flatbeds to increase the loads they can haul and client base. With used flatbeds and dry vans available for under $10,000 and used refrigerated units under $20,000. With a relatively small investment a small motor carrier can maximize the use of an $80,000 to $120,000 investment in a new or recent model year truck tractor.

Life expectancy for semi trailers, that simply don't get as many miles as most truck tractors, can easily be twelve to twenty years or more. Reconditioning semi trailers is a cottage large industry. I have seen reconditioned 35-year-old food grade tankers that looked like new.

Over the road (OTR) truck tractors have a typical operational use six to seven years during which time they can easily accumulate one million miles. After this time, most are either worth more for spare parts or *semi*-retired to local use or modified into straight trucks.

We can expect a disproportionate ratio of ABS truck tractors towing non-ABS semi trailers for many years to come. At this time there is no anticipated regulation to require the retrofitting of pre-1998 trailers with aftermarket ABS systems. Retrofitting can often approach the total value of the used semi trailer.

Most drivers are not aware of this potential trailer swing problem and will only experience it during a hard or emergency braking situation. (Not the best environment to learn how to handle an unintended vehicle movement).

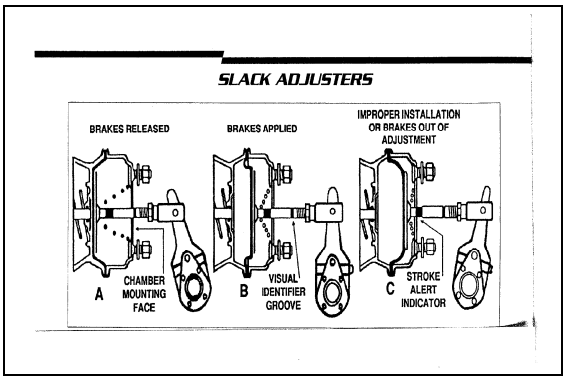
Many states have amended new Commercial Drivers License (CDL) manuals. The vast majority of CDL holders were trained and tested under earlier editions that do not address ABS brake systems or how to properly brake in an emergency situation with the new technology.

NHTSA was aware of these potential problems when the regulation was studied. Facing a great deal of industry opposition due to added cost for installation and maintenance as well as research and development considerations federal authorities felt the benefits worthwhile and moved forward.

As the saying goes, "its better to light a candle than curse the darkness" or as the officials usually say in "government speak", the potential cost to the industry is outweighed by the expected benefit to the safety of the CMV operators and motoring public.

Self-adjusting brakes

Self-adjusting brakes, automatic slack adjusters (ASA) also known as self adjusting slacks (SAS) attached to brake chambers with stroke alert indicators help keep brakes balanced, reduce brake shoe to brake drum travel distance and give the mechanic and driver a visual cue if the automatic adjusters have failed.



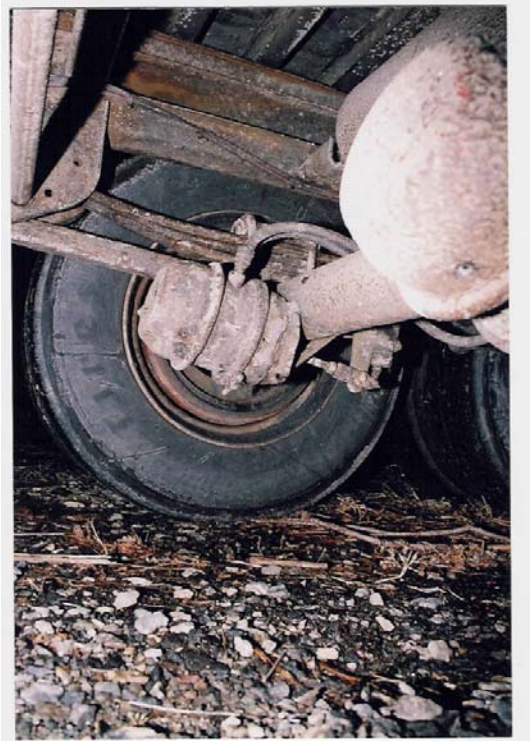
Stroke alert indicator

This standard for all air brake equipped vehicles manufactured after October 20, 1994 should have reduced the number of brake defects. However, self-adjusting (ASA) brakes do not mean maintenance free brakes.

These units have been available for many years prior to 1994 but were not widely accepted. ASAs effect adjustment by either movement of the slack adjuster's relative position to the camshaft or by movement of an adjusting link by an extended yoke at the end of the air chamber pushrod beyond a predetermined angle or degree of rotation. This occurs during brake application.

In order to function properly, the ASA must be installed at the proper angle, adjusting link or strap secure and must be kept lubricated according to manufacturers recommendations. To ensure the automatic function has the opportunity to adjust, the brakes must be applied with sufficient air pressure so

that the air chamber pushrod moves the required distance to effect adjustment, if needed.



Type 30/30 air chamber with Meritor™ ASA

Ironically, a conservative driver that uses engine retarders ("Jake brakes"), downshifts and applies brakes with light application pressures may not apply the brakes hard enough for them to adjust. The vehicle need not be in motion to activate the mechanism. The air pressure should be brought to maximum cut out (usually 120 PSI) and then a full, maximum brake application made. If this is done on a daily basis the ASAs will have an opportunity to adjust, if needed. This procedure also has the added effect of testing the entire system at maximum application pressure. If something is going to blow out, you want it to occur during your pre trip inspection, not during an emergency braking situation.

Mechanics should be taught to use this procedure during preventative maintenance checks. They should be particularly sensitive to the "Stroke Alert Indicator" and the "Visual Identifier Groove".

The "Stroke Alert Indicator" is a red or orange mark at the base of the pushrod. It indicates the air chamber push rod has extended to a point at or beyond the adjustment limit. If this can be observed under full brake application, (80 – 90 PSI at the air chamber or at least 100 PSI in the reserviors) the ASA is either not functioning or has been improperly installed. It needs immediate attention and repair.

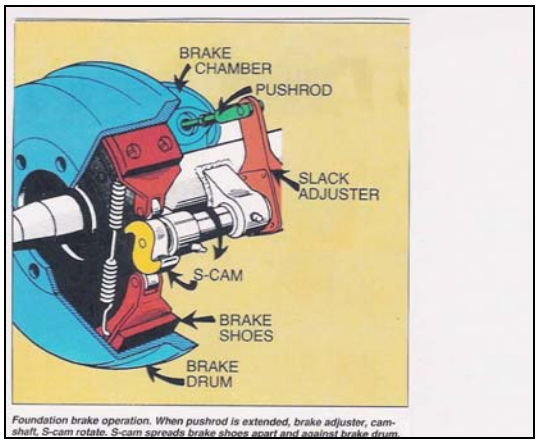
Another often-overlooked item is the "Visual Identifier Groove". This mark on the pushrod should be flush with the face of the air chamber with the brakes and parking brakes fully released. ***(CAUTION: WHEELS MUST BE CHOCKED WHEN CONDUCTING THIS INSPECTION!)***

Proper function of the ASA is dependant on full movement of the slack adjuster from released to the applied position. If the pushrod does not fully retract, the ASA may not adjust properly if at all. A pushrod that does not fully retract may be caused by poor lubrication, weak or broken return springs, broken spring brake on double chambers. Binding in the camshaft, worn clevis pins, broken self-adjusting mechanism, can also cause a failure to fully retract and adjust.

Worn Camshaft and brake drum failures

The slack adjuster is mounted on the end of the camshaft. When the brakes are applied, the slack adjuster rotates the camshaft, which rotates the "S" cam

forcing the brake shoes apart and against the brake drum.



Camshaft between "S" cam & slack adjuster

The camshaft has bushings at each end that can and do wear. Lack of lubrication decreases life of these bushings. Worn bushings allow the camshaft to move at an angle and may bind or cause excessive wear to the ASA mechanism.

A more important issue is the relative position of the brake shoes in relation to the brake drum. The camshaft actually serves two functions. The most obvious is the rotation of the "S" cam and brake application.

The second is allowing the "S" cam to be the platform for the brake shoes at rest when the brakes are released. In the normal condition with the brakes released, the upper and lower brake shoes are held back by return springs against the "S" cam at equal distances from the brake drum. If the camshaft bushings are worn, the lower brake shoe is closer to the drum when the brakes are released. The ASA, is designed to minimize the brake shoe to drum clearence.

As the bushing wears, the bottom brake shoe will eventually drag against the brake drum when the brakes are released. This results in overheating of the brake drum, excessive heat checks, and brake drum wear. If not repaired, the brake drum will begin to crack and the ASA will continue to over adjust the brakes hastening the drum failure.

Worn bushings were not as significant a problem with manual slack adjusters as the mechanic simply had to back off the brake an additional ¼ to ½ turn when adjusting, to compensate for the lower brake shoe drag. Brakes would require more frequent adjustments, but the overheating problem from dragging brakes could be compensated.

The maximum recommended play in the camshaft for either manual or automatic slack adjusters is 0.30". Camshaft bushings can be replaced with either nylon or roller bearing bushings provided the shaft is not damaged. The entire foundation brake assembly must be dismantled to remove and replace these bushings.

Conversion of truck tractors to trucks

It has been a practice for many years to take used truck tractors that have served a long and noble life in OTR operations, to end up in "*Semi-retirement"* after being converted into some type of straight truck, dump truck or wrecker. Air brake systems up to the mid 1980's were fairly generic between trucks and truck tractors and required little or no modification if converted.

By 1987, Bendix-Westinghouse (now Allied Signal) aggressively sought to reduce the risk associated with operating

bobtail truck tractors (truck tractors without semi trailers attached). They offered new valves referred to as the "Bobtail Proportioning Valve". They have been marketed as the BP-1 & BP-R1 valves.

These two models of the valve were designed and have been very effective in reducing lateral control problems associated with over braking on the rear of the truck tractors. They are activated when the trailer supply line (the red hose to the semi trailer) and the trailer supply valve on the dashboard are closed. The valve reduces the rear brake pressure as much as 75% while allowing full brake pressure to the steering axle. If a full brake application is made, the rear brake pressures will quickly rise once 60-65 PSI application pressure is achieved.

These valves became very popular on truck tractors since the 1992 model year and are still used on some ABS systems.

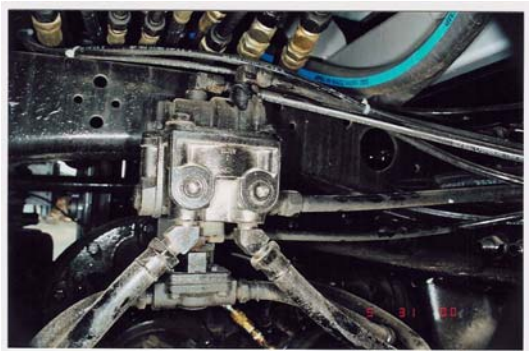
The sudden growth of the motor carrier industry in the mid to late 1990's has now resulted in an extreme overstock of used truck tractors. As a result those who need a heavy duty straight truck are increasingly finding clean, low mileage, well equipped truck tractors at a fraction of the cost of a new, lighter chassis straight truck. Even with conversion costs it has become an attractive alternative to many truck users. Due to the overstock, many dealers are offering reconditioned truck tractors with up to 200,000 mile / 2 year factory warranties.

Freightliner Corporation recently opened a reconditioning plant in Utah that will provide used trucks to order, including custom interiors and paint that appear as a new unit.

When converting a truck tractor into a straight truck, it is important to ensure the second stage manufacturer checks the brake valves and make any necessary modifications.

While investigating several complaints of poor braking on vehicles that had been converted from truck tractors to heavy duty wreckers and one that had been converted to a race car hauler / motor home I found the BP-R1 as the common denominator. The complaint was always the same. The vehicles would seem to have very limited braking at normal application pressures and as the pedal pressure was increased, the brakes would surge and the vehicle would jerk to a stop.

Attachment of a Gooch™ Air Brake Analyzer quickly identified the problem. The truck still thought it was a truck tractor. With no semi trailer attached the trailer supply line was closed and the BP-R1 was doing exactly what it was designed to do. It was reducing the rear brake pressure until the brakes were applied above 60-65 PSI and the rear brakes would then kick in.



BP-R1 valve with its distinctive three-tier valve incorporated into the top of a relay valve.

The solution was quite simple. Either replace the BP-R1 with a standard relay valve or plumb the control line, (a

narrow line that connects the top of the valve to the trailer supply / tractor protection valve) into a supply reservoir. The plumbing of the control line into the reservoir gives the BP-R1 the same signal as when a semi trailer is attached and the relay valve reverts to its normal full brake pressure relative to the steer axle.

I checked to see the magnitude of the problem. NTSB led me to A. Marvin Sprinkman and Donnie A. Nichols of the California Highway Patrol Commercial Motor Vehicle Major Accident Investigation Team (CHP/MAIT). They had conducted a similar investigation and established an inspection protocol for testing converted trucks from truck tractors. If the valve has not been properly modified, they will declare the vehicle out of service. The CHP/MAIT officers also forward an article warning of this potential problem published in the Commercial Carrier Journal, an industry publication.

Availability of test equipment to maintain the new technologies

The new technologies are incorporating and in some cases requiring the use of computers and proprietary data collectors for routine maintenance tasks. As I overheard in a truck parts store recently, "The days of the shade tree mechanic are numbered".

Manufacturers are now faced with the difficult decisions as to how much proprietary information are they willing to share in the public domain while making data acquisition generic and affordable to the end user. The Society of Automotive Engineers (SAE) is addressing this task with recommendations for common data collection cables, software and standards.

Virtually all heavy truck diesel engines manufactured since 1997 are computer driven and are acquiring other data important to engine functions, air brake ABS functions and electronic interaction with the transmission and drive train. Many automatically record "Hard Braking Incidents" if the vehicle decelerates at a rate of 7 mph/second (10 FPS/S or 31% relative to the force of gravity).

Cost of data collection software and hardware typically range from $800 to over $3000. Motor carriers, maintenance and law enforcement personnel will need to budget for this additional expense to evaluate, maintain and analyze the new technologies for maintenance as well as collision reconstruction and collision prevention research.

Performance Based Brake Testers (PBBT)

The FMCSA and NHTSA have been evaluating Performance Based Brake Testers (PBBT) for enforcement use. These systems have been widely used in Europe for over ten years in routine inspections and are currently used by major US truck & bus manufacturers to test new units before they leave the factory. The PBBT is available in several designs, all with the intent to test the brake force on a vehicle in relation to its actual weight.

The systems must be capable of measuring the amount of weight and brake torque at each wheel to determine

if it can generate a minimum standard brake force of 0.40 g (40% of the vehicle's gross weight). This is consistent with the FMVSS minimum brake performance with the air braked vehicle loaded to its GVWR of 0.40 – 0.41 on a Skid Number 81 surface.

Testing has been conducted comparing 20 mph deceleration tests with PBBT predicted deceleration values. The correlations have been very good and most styles of PBBTs tested did predict the deceleration rate within Acceptable Ranges of Repeatability (ARR).

Several of these units have been tested by MCSAP and the Commercial Vehicle Safety Alliance (CVSA) trained officers as a pre-screening device to identify CMVs for Level I inspections (full under vehicle mechanical and driver paperwork inspection).

Portable roller PBBT

The PBBT will likely be approved to become the enforcement standard by the end of 2001. Rather than just being used as a pre-screening device, PBBT results will be used for enforcement. If a CMV can't develop the minimum brake performance or the brake balance on steer axles is over 50% different, the vehicle would be declared OOS.

The inspector would be relieved of having to crawl under the CMV to measure the brakes. As the test on the PBBT takes about 5 minutes (1 minute per axle) it should increase the number of CMV brakes inspected and reduce the time legal trucks are detained for inspection.

A strong proponent for the PBBT is Richard "Dick" Radlinski, former head of heavy vehicle testing for NHTSA at the Transportation Research Center (TRC), East Liberty, Ohio. Radlinski, studied the European systems for several years before his retirement after 28 years of service to NHTSA.

He is now, now president of RAI-Braking System Consultants, and conducts research and development for most major air brake component and vehicle manufacturers. He has supported and contributed to validation testing for the FMCSA at TRC and now represents one of the major PBBT manufacturers.

His product, the BM20200 roller PBBT is an electric treadmill design, which rotates the vehicle's wheels and measures the brake force as the brakes are applied. The roller PBBT is one of the only practical ways to dynamically test ABS, and traction control systems.

These testers have revealed ABS equipped CMVs with crossed wiring harnesses. This wiring defect could easily result in false signals to the Electronic Control Module (ECM) and release a braking wheel while the actual sliding wheel remains locked. This would result in an increase in stopping distance and possible loss of lateral stability. This defect would not be

detectable to the driver or mechanic under normal stationary testing or driving conditions. Absent a roller PBBT, it would only be noticeable under emergency braking conditions.

This PBBT can be equipped to weigh the vehicle and monitor brake pedal pressure while the test is being run. It is also available with an optional weight simulator. The weight simulator is a hydraulic system that attaches to the axle pulling it down against the treadmill. It can simulate weights up to 40,000 pounds.

This unit is available as an in-ground or a portable unit that weighs 2600 pounds. It can be transported on a car trailer and operated at random roadside or collision sites with a 3-phase/240-volt/14KW gasoline powered generator.

The roller brake tester (PBBT) can test accident vehicles provided the wheels are still on or can be replaced on the axles. Since the roller rotates the wheels independent of the drive train, a vehicle can be tested if it can be towed onto the unit and a remote air supply can be attached to the vehicle or axle.

The PBBT is being primarily being made available through MCSAP funding for use by CMV inspections, but the unit can also test hydraulically braked cars and trucks. It is particularly useful to quantify brake shoe friction loss from fluid contamination.

Stopper & Associates recently purchased a portable PBBT with weight simulator. We will be conducting validation tests for calculating brake force and deceleration rates at speeds above 20 mph for use in collision reconstruction analysis. These brake force calculations will also be compared to the REC-TEC Truck Brake computer software program. The REC-TEC Truck Brake Program is based on the brake force calculation methodology developed by Ron Heusser, former NTSB engineer and highway collision investigator, first published in the NTSB 1992 Truck Brake Study.

Summary

New technologies will only help reduce system failures and collisions if they are properly applied and maintained. It will be important to the motor carrier industry, drivers, mechanics, CMV inspectors and reconstructionists to keep updated on these changes and have access to the proper tools to test and maintain these systems.

New issues as to applicability and admissibility of “black box” data, that are becoming the motor vehicle industry standard, are already being addressed in many court cases. This is quickly becoming yet another case where the technology has proceeded the law.

Collision investigators will need to become more familiar with and sensitive to the available data. It will become increasingly important set up protocols to either acquire hardware and software for this purpose or set up a network of reliable sources and / or motor vehicle dealers that can provide the equipment or service of downloading the data to ensure accuracy and admissibility in court proceedings.

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5. **Stopper & Associates www.TruckStopper.com**
6. **REC-TEC Accident Reconstruction Software www.rec-tec.com**