Air Brake Failure- Automatic Slack Adjuster (ASA) - Air Brake Chamber Failure Analysis

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Abstract

Air brake equipped heavy trucks, trailers and buses manufactured since late 1994 were originally equipped with self adjusting brakes. Many commercial motor vehicle (CMV) drivers believe there is little need to thoroughly inspect self adjusting air brakes while still others are in the habit of manually adjusting these brakes, which in some cases can actually damage the mechanisms.

A disturbing number of CMVs involved in injury and fatal traffic collisions equipped with self adjusting air brakes are still found with brakes out of adjustment.

Many air braked vehicles equipped with automatic slack adjusters (ASA's) are still found in an under adjustment condition with inoperative or malfunctioning self adjusting mechanisms.

Adjustment failures can be as obvious as a disconnected adjusting mechanism (a/k/a: adjusting link) or as subtle and concealed as air brake chambers with weak return springs or fractured parking brake power springs.

This paper discusses several defects and methodologies for failure analysis important to maintenance professionals, CMV inspectors and collision reconstruction professionals.

All of the examples discussed have been found on vehicles involved in serious injury and fatal traffic collisions involving CMVs.

1994 FMVSS Requirements

Air braked vehicles subject to Federal Motor Vehicle Safety Standard (FMVSS) 49 CFR §571.121 and Commercial Motor Vehicles (CMV) subject to Federal Motor Carrier Safety Regulation (FMCSR) 49 CFR §393.53(b),(c), manufactured after October 20, 1994 are required to be equipped automatic brake adjusters. In addition, if the foundation brakes are equipped with air brake chambers that have exposed air chamber push rods, a visual cue is required to indicate an under adjustment condition.

The FMVSS regulation uses the term "automatic brake adjusters" or ABAs. This term is inclusive of multiple current designs and allows for alternate new designs. The most common version of the automatic brake adjuster is the automatic slack adjuster (ASA). These are applicable both as original equipment manufacture (OEM) and after market retrofit on pre 1994 vehicles. Manual slack adjusters and ASAs are an essential component to "S" cam, "T" cam and some air disc brake applications.

Code of Federal Regulations:

49 CFR §571.121 S5.1.8 applies to trucks, buses and truck tractors.
49 CFR §571.121 S5.2.2 while identical, applies to trailers.

49 CFR §571.121 (FMVSS 121) is applicable to manufacturers.

49 CFR 571.121 S5.1.8 Brake distribution and automatic adjustment. Each vehicle shall be equipped with a service brake system acting on all wheels.

(a) **Brake adjuster.** Wear of the service brakes shall be compensated for by means of a system of automatic adjustment. When inspected pursuant to S5.9, the adjustment of the service brakes shall be within the limits recommended by the vehicle manufacturer.

(b) **Brake indicator.** For each brake equipped with an external automatic adjustment mechanism and having an exposed pushrod, the condition of service brake under-adjustment shall be displayed by a brake adjustment indicator that is discernible when viewed with 20/40 vision from a location adjacent to or underneath the vehicle, when inspected pursuant to S5.9.[1]

49 CFR §393 - PARTS AND ACCESSORIES NECESSARY FOR SAFE OPERATION is applicable to motor carriers.

49 CFR §393.53 Automatic brake adjusters and brake adjustment indicators.

(b) **Automatic brake adjusters (air brake systems).** Each commercial motor vehicle manufactured on or after October 20, 1994, and equipped with an air brake system, shall meet the automatic brake adjustment system requirements of Federal Motor Vehicle Safety Standard No. 121 (49 CFR 571.121, S5.1.8) applicable to the vehicle at the time it was manufactured.

(c) **Brake adjustment indicator (air brake systems).** On each commercial motor vehicle manufactured on or after October 20, 1994, and equipped with an air brake system which contains an external automatic adjustment mechanism and an exposed pushrod, the condition of service brake under–adjustment shall be displayed by a brake adjustment indicator conforming to the requirements of Federal Motor Vehicle Safety Standard No. 121 (49 CFR 571.121, S5.1.8) applicable to the vehicle at the time it was manufactured. [2]

Discussion

First and foremost, a properly installed, lubricated and maintained ASA connected to properly functioning air chambers and foundation brake components will not need manual adjustment. If manual adjustment is required to maintain proper adjustment levels the ASA function should be diagnosed, repaired and/or replaced.

It is important to understand that a malfunctioning ASA does not always result in a complete brake failure, but can contribute to brake imbalance, uneven brake wear and ultimately failure or reduced efficiency of the subject brake. As ABAs are required equipment on vehicles subject to the FMCSR manufactured after October 1994 it is a violation of those regulations to operate a CMV with defective ABAs even if they can be manually adjusted.

§393.1 "No employer shall operate a commercial motor vehicle, or cause or permit it to be operated, unless it is equipped in accordance with the requirements and specifications of this part." **Ibid[2]**

[1] Transportation; 49 CFR Parts 400 – 999 ; FMVSS §571.121 S5.1.8 & S5.2.2; Government Printing Office, Washington, DC

[2] Transportation; 49 CFR Parts 200 – 399 ; FMCSR §393 - Parts and Accessories Necessary for Safe Operation; Government Printing Office, Washington, DC

Many of the problems to be discussed were published in the NTSB Highway Accident Report, Mountainburg, AR[3] involving multiple brake failures which resulted in a fatal truck tractor, semi trailer crash with a school bus resulting in 3 fatalities and 8 injuries.

Personal involvement in this brake failure analysis and accident reconstruction as well as the NTSB investigation revealed a combination of poor maintenance as well as component failures. These allowed multiple brakes to operate with reduced efficiency and progressively fail contributing to this fatal collision.

Reconstruction analysis in the Mountainburg, AR case revealed that had any one of the many brake defects not been present, the driver could have developed sufficient brake force, although severely compromised, to have avoided the collision with the school bus.

Over ten years after the ABA requirement, most air brake vehicles are now equipped with ABAs, the vast majority being ASAs. Still a disturbing number of air brake vehicles are found with brakes beyond allowable adjustment limits.

Many failures are the result of ASA equipped units now showing significant normal wear and requiring preventative maintenance. Many are being replaced by mechanics that do not have specific training or fail to follow critical procedures in service and replacement of ASAs.

In some cases, motor carriers and owners operators simply remove ASAs, replacing them with non OEM manual slack adjusters. This is a violation of 49 CFR §393.53 & 396.3 (a)(1) if the vehicle was manufactured on or after October 20, 1994.

While many failures are found on older units, do not assume ASAs are functioning properly on new vehicles. According to the Commercial Carrier Journal *"Incorrect factory installation of ABAs is a common problem on new vehicles. Add this item to your pilot and pre delivery inspections".*[4]

While properly maintained ASAs can have an operating life of ½ million miles or more, it is not unusual to find over the road CMVs accumulating 600,000 miles in less than three years. Trucks and buses used in heavy duty and urban service will often require ASA service or replacement in much shorter intervals.

CVSA Brake Inspections

Each year, the Commercial Vehicle Safety Alliance (CVSA) coordinates an announced nationwide roadside CMV brake inspection over a three day period combining enforcement and educational efforts. This annual inspection is widely published throughout the trucking industry, months in advance, specifying the dates and in some cases, the locations of the inspection sites.

[3] National Transportation Safety Board, *Collision Between Truck-Tractor Semitrailer and School Bus Near Mountainburg, AR on May 31, 2001*, NTSB/HAR-02/03; PB2002-916203; Adopted September 4, 2002.

[4] Taking Out The Slack; Gerald Standley; Commercial Carrier Journal; Air Brake Book 6th Revised Edition; 1998.

In spite of this well known annual enforcement effort, the September 2004 announced "Operation Air Brake" enforcement drive found nearly one out of five (17.9%) of CMVs inspected to be operating with defective brakes to the level of being declared "Out Of service".

The CVSA, whose committee members include law enforcement and industry representatives, publish the standards for the "OOS" (Out Of Service) criteria typically endorsed by the FMCSA (Federal Motor Carrier Safety Administration).

The OOS criteria allow a CMV to continue in operation with up to 20% of the brakes with identified defects. The OOS will not count a defective ASA so long as the push rod stroke is within allowable adjustment limits at the time of inspection.

Defective ASAs are often not noted or simply overlooked in typical CVSA Level I inspections. As a result, air braked vehicles with defective and inoperative ASAs can continue to be operated indefinitely provided the operator of the vehicle continues to over ride the automatic brake adjustment function and manually adjust the brake.

Operation of Automatic Slack Adjusters

ASAs have been available for over 20 years as optional equipment before becoming mandatory for air brake vehicles in October 1994.

While some improvements and additional competitive products have been developed, ASAs all operate by two basic hardware styles, both dependent on the amount of rotation of the cam shaft or power shaft relative to the air chamber push rod stroke.

The most popular design is similar to the manual slack adjuster with an adjusting link attached between an extended push rod clevis and the adjusting mechanism connected to internal adjusting linkage.

Type 30/30 Air Chamber & Meritor® ASA
Note: Central™ "Wheels-On" Drum Gauge in background

Brake application results in the geometry between the cam shaft, slack adjuster and adjusting link to change, causing the adjusting link to rise and fall in relation to the slack adjuster housing.

As push rod stroke increases by foundation brake component wear, the adjusting link movement becomes greater. At a predetermined point, the adjusting link rotates the adjusting nut to the next adjustment level where the internal mechanism locks the adjusting nut in place. Each adjustment is typically ⅛ turn of the adjustment nut.

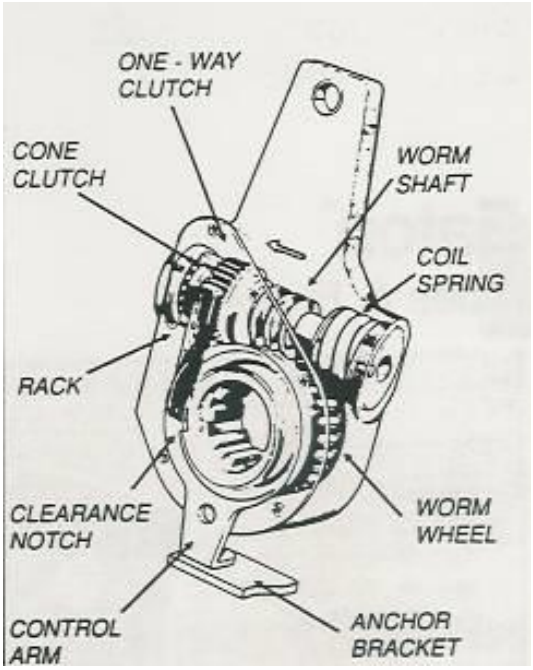
Due to manufacturer design considerations, some models of ASAs perform the adjustment on the application stroke (Gunite™, Allied Signal/Bendix™) while others adjust on

the release stroke (Arvin/Meritor™, Rockwell™, Crewson-Brunner™).[5]

Creson-Brunner™ "Auto-Check" ASA

The Crewson-Brunner ASA has incorporated a unique permanently mounted template which easily allows a driver to evaluate brake adjustment.

The second ASA design unique to the Haldex S-ABA™ (Self Setting Automatic Brake Adjuster) utilizes an anchor bracket. This alternate design attaches the internal adjustment mechanism via an anchor arm that encircles the cam shaft. The anchor arm is then attached to a fixed point by a bracket typically attached to the axle, brake spider or to a mounting bolt of the air brake chamber.[6]



Haldex S-ABA™

Haldex™ ASA – Control arm worn through anchor bracket & excessive wear at clevis pin bushing

Adjusting Link Geometry

The geometry, more commonly referred to as installation angle, is critical to proper function of ASAs equipped with a pushrod clevis actuated adjusting link. This includes all current designs with the ***exception of the Haldex S-ABA™.***

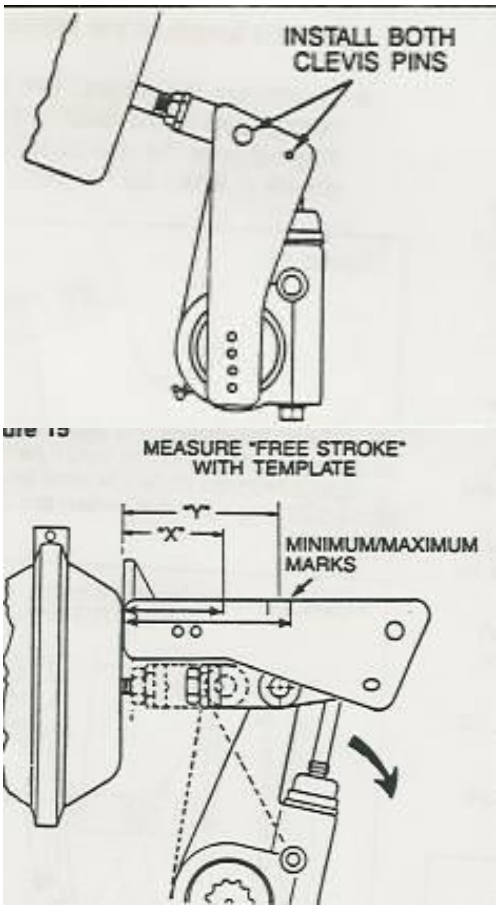
The angle created by the three center points between the cam shaft, clevis pin and adjusting link clevis pin are critical

[5] The Air Brake Book; 6th Revised Edition, Commercial Carrier Journal, 1998; Cahners Business Information

[6] TMC-Technology and Maintenance Council, Recommended Practice – RP 609; Manual and Automatic Slack Adjuster Removal, Installation and Maintenance; 2002 Edition.

to insure proper adjustment as well as to prevent over adjustment.

The ASA must be checked with a template supplied by the manufacturer.



Installation inspection with Meritor™ template

There are subtle differences in many designs between ASAs for trucks, truck tractors, trailers and air disc designs. It is also important to insure the ASA is the proper model for the air chamber to which it will be connected.[7]

Meritor (formerly Rockwell) uses a color coding system. The nylon strap tie that secures the rubber boot on at the adjusting link shows a different color for various air chamber "Type" sizes. In recent years the color coded nylon strap has been eliminated however the "color" is still identified on a label on the ASA.

Meritor™ ASA identification label

Brake maintenance mechanics and professionals making a forensic analysis can not assume that successful connection of the linkage has resulted in proper ASA adjustment. Confirmation of installation angle must be confirmed with the appropriate template.

Push Rod Length

New and replacement air brake chambers generally are provided with a 12 inch push rod which must be cut to proper length depending on the specific installation requirements.

If cut too short, when the clevis is connected, the slack adjuster it may contact axle components, restricting full retraction. This prevents the ASA from completing a full apply to release cycle and will not allow proper automatic adjustment.

Even without contact with axle components a push rod cut too short will generally require the installer to pull the push rod out to allow connection of the adjusting link to the clevis. When this occurs, the adjusting link in the released

[7] Meritor Automotive Systems, Field Maintenance Manual 4-B,

position, will reach its mechanical limits causing the pushrod to remain in a partially applied position.

In the Mountainburg, AR fatality case NTSB wrote:

"During the post accident inspection, investigators discovered that the angle between the pushrod and the slack arm on brake 4R (semitrailer left leading axle) was greater than the 90 degrees that specifications allowed. When measured against a slack adjuster template, the pushrod was about 1 inch shorter than the pushrod on the left side of the trailer, causing the greater angle. According to the manufacturer, the automatic slack adjuster was bottoming out, thus preventing full release of the pushrod and preventing the brakes from automatically adjusting. The 4R brake drum was rusty and the brake did not appear to be functioning."

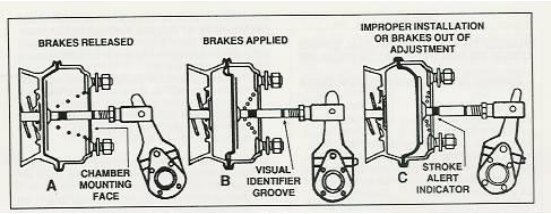
In this circumstance, when the push rod stroke is measured in accordance with CVSA recommended practice, the push rod stroke may measure within adjustment limits when in fact it is beyond the limits. The effective push rod stroke will be the measured push rod stroke plus the distance the push rod is being suspended in the partially released position.

Due to the shortened push rod stroke, the ASA will not sense the need for adjustment and will allow an out of adjustment condition to develop.
At the time of this improper installation and periodic maintenance, if the mechanic notices excessive brake block to drum clearance and manually adjusts the automatic slack adjuster, this condition could continue indefinitely even though the ASA is not functioning. If cut too long, the adjusting link will either be restricted in cycle movement so as not to adjust or only adjust well after the push rod stroke is beyond the adjustment limit.

Defective Air Brake Chambers

Often overlooked and difficult to diagnose are worn out air brake chambers. Most inspections of air brake chambers only involve a check for leaking air diaphragms and connecting air hoses. Few drivers, mechanics and CMV inspectors are sensitive to or even aware of the brake adjustment indicators required since 1994 and used by most air chamber manufacturers for several years before the FMVSS and FMCSR requirement for an external automatic adjustment identifier. Ibid[1] [2]

Air brake chambers manufactured for the last ten years are typically marked in two ways. First with a "stroke alert indicator", marking which visually identifies when a push rod has reached the adjustment limit. This is typically a red or orange ring marking the last ½ inch of the push rod which is exposed whenever it is at or beyond the adjustment limit.



Stroke Alert Indicator

MGM uses a green (within adjustment limit), yellow (nearing the adjustment limit) and red (at or over adjustment

limit) color code. This style is pasted on the push rod and is subject to deterioration as a result of extended operation.

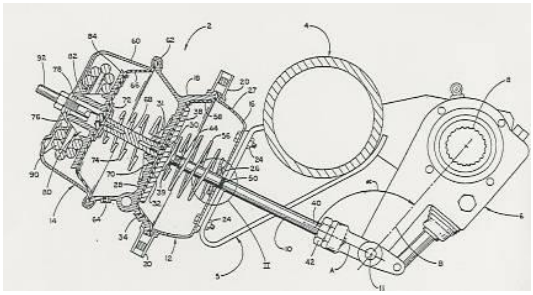
The second common marking is referred to as a "visual identifier groove". This is an identification point on the push rod which should be flush with the face of the air chamber when the brakes are released.

Exposed "Stroke Alert Indicator"
Brake at maximum stroke

The adjustment indicator was discussed for many years and was finally made a requirement after the National Transportation Safety Board (NTSB) recommendation in the 1992 Heavy Truck Airbrake Performance Safety Study.[8]

This long overdue safety enhancement was welcome but unfortunately has been poorly publicized and unknown to most drivers of air brake vehicles. It is not currently discussed in Commercial Drivers License Manuals.

Inspection of combination "Service / Spring brake" air chambers have revealed fractured power springs in the parking brake segment of the dual section chambers.



Typical Type 30/30 Spring-Service Brake & ASA[9]

An investigation by the author and the NTSB of the collision between a loaded truck tractor, semi trailer and school bus near Mountainburg, Arkansas in 2001 revealed numerous brake deficiencies.

The brake deficiencies leading to multiple fatalities in the school bus struck included this summary from the NTSB "Factual Information" report:

"The parking/emergency brake spring was found to be in three pieces when brake disassembled. After a manual caging bolt was installed, the chamber retracted an additional 5/8 inch, indicating that the broken spring was preventing full pushrod release. The spring was fractured in such a way that it prevented full return of the pushrod; thus, the automatic slack adjuster did not have the minimum 1½ inches of

[8] "Heavy Vehicle Airbrake Performance," Safety Study, National Transportation Safety Board, P892-917003, Washington, DC, Adopted April 29, 1992.

[9] United States Patent #5002164; US Patent Office, Arlington, VA

stroke necessary to activate the adjusting mechanism." Ibid 3

In this case it became apparent three brake chambers inspected were at or near maximum stroke (bottomed out) but still measured to be at or near allowable push rod stroke limits. Further examination through the "Caging bolt" hole at the end of the brake chamber revealed a tilted pressure plate. NTSB investigators removed the suspect air brake chambers and had a manufacturer's laboratory disassemble them exposing the fractured power springs.

Disassembled Type 30/30 brake chamber
with fractured power spring

Inspection of a service-spring brake chamber suspected of a fractured power spring requires great care. Disassembly should NEVER be attempted except by a professional equipped with a proper compression press and safety cage. Failure to do so could result in serious injury or death. Visual inspection, without dismantling can be conducted with a bore scope.

Measurement of the push rod stroke on an air brake chamber with a suspected restriction of movement can accurately be attained by inserting a narrow ruler along the push rod.

First, with the wheels of the vehicle chocked, release the parking brakes with normal air pressure (100 – 125 PSI). Insert a narrow ruler along the push rod to the base of the push plate. Measure the distance from the retracted push plate to the face of the chamber.
The thickness of the internal mounting bolts and the chamber body is normally ½".

If the chamber push rod is retracting properly, the measurement should be equal to the maximum push rod stroke plus ½". A standard Type 30/30 chamber push rod stroke adjustment limit is 2" with a maximum stroke of 2 ½". If fully retracted, the distance from the face of the chamber to the internal push plate should measure 3".

If the measured distance is less, the effective push rod stroke will be the measured stroke at an 85 – 90 PSI brake application, plus the difference between the proper fully retracted measure and the actual measure.

Current maintenance and inspection procedures do not directly address inspection for fractured power springs. NTSB reported:

"A broken spring, which is difficult to detect, can reduce emergency-parking brake forces or render the emergency-parking brake inoperable, and the broken spring pieces can be displaced, thus shortening the pushrod stroke or preventing the automatic slack adjuster from functioning. The extent of the broken spring problem is undetermined.

Radlinski and Associates, a brake consulting firm, reported to investigators

that in an inspection of 11 five-axle combination trucks at a large firm with an excellent maintenance program, an inspector found an average of two broken spring brakes on each tractor semitrailer."

Broken spring brakes are not an out-of-service item if detected during CVSA inspections, nor is visual examination of spring brakes an inspection item. Regulations do not require use of dust covers over the caging port to prevent contaminants from getting into the spring brake assembly.

Weak Return Springs

Both service and service/spring air brake chambers are equipped with return springs to retract the push rod and slack adjuster to its fully released position.

ASAs must return to the fully retracted position to accurately sense the push rod stroke and determine when automatic adjustment is required. The most popular ASAs adjust on the return stroke. To achieve full retraction, the cam shafts and slack adjusters must be properly lubricated and the air chamber return spring needs a minimum of 32 pounds of spring force to effect full retraction and adjustment.

Cam Bushings & Clevis Pins

Another area often overlooked is the condition of the cam bushings and clevis pins. ASAs require proper alignment and lubrication to maintain brake adjustment levels. They have to be sensitive to brake wear while not over adjusting.
As a result, excessive play in the attaching components will permit the push rod excessive movement without the ASA sensing the need for adjustment.

Paul Richards, Executive Editor for Commercial Carrier Journal wrote:

"Clearance between the slack adjuster clevis pin and its bushing should not exceed 0.020".

"Check cam shaft splines for free play between the slack adjuster and the camshaft. The cam shaft and/or slack adjuster should be replaced if there is more than 0.020" free movement between slack and camshaft."[10]

Cam bushing play must be checked with the brakes released. With brakes applied, the pressure and torque of the brake application will take the play out of the system masking excessive play. "S" cam shaft bushing play should not exceed 0.040". Ibid 7

Disassembled Rockwell ASA

[10]Restoring S-Cam performance; Richards, Paul; CCJ/The Air Brake Book, 6th Edition, 1998

Internal adjusting mechanisms are sensitive to the introduction of excessive dirt and corrosion from road dirt.

Worn adjusting link rubber boot

Worn rubber boots, protecting internal parts must be inspected. If worn or torn, the ASA must be disassembled, cleaned and the boot replaced. Often labor cost exceeds the value of simply replacing a worn ASA.

Manual Adjustment an ASA

Drivers and mechanics often insist on manually adjusting ASAs. In the case of Meritor ASAs, the adjusting pawl, which locks the adjusting sleeve preventing the worm gear from backing off, like a ratchet wrench, can be damaged by manual adjustment.

It is common practice in manual adjustment for the brake shoes to be brought to firm contact with the brake drum then back off the adjustment nut ¼ to ½ turn. This allows for minimum shoe to brake drum clearance.

The manual adjustment nut on the end of the Rockwell / Meritor ASA will allow the brakes to be tightened but the pawl must be released or removed before backing the brakes off.

Meritor has reduced the size of the adjusting nut in an attempt to prevent the drivers from using a large enough wrench to back off the brakes without releasing the pawl. They also added a "Pull-pawl", a spring loaded cap on the pawl nut that can be lifted without removing the pawl allowing disengagement of the adjusting link during manual adjustment.

Worn/damaged Rockwell / Meritor ASA adjusting pawl

Other manufacturers of ASAs use a variety of clutch spring assemblies to hold the automatic adjustment while still allowing manual adjustment.

Excessive manual adjustment can cause these clutch springs to weaken and fail to maintain adjustment. To test the clutch spring, a torque wrench must be used to test the holding strength of the manual adjustment nut. These vary between manufacturers and service manuals need to be consulted for these torque values.

Push Rod Strokes for ASAs

The general thought since the onset of manual slack adjusters was to adjust the brakes so that the push rod stoke is as short as possible without the brakes dragging the brake drums, in some cases as little as 1/2" push rod stroke. This is not necessary the case with ASAs.

The ASA needs enough push rod stroke to allow full application but still enough brake shoe to drum clearance so the brakes don't tighten during brake drum heat expansion and then drag when the drums cool. As a result, properly installed and functioning ASAs will typically operate with push rod strokes much closer to the adjustment limit. In the case of a Type 30 brake chamber, 1 1/2" to 1 7/8" are typical with 2" as the adjustment limit and 2 1/2" at maximum stroke.

The importance of this is when an ASA mechanism does fail to adjust automatically, it will run beyond the adjustment limit sooner than a manual adjustment that is left unattended.

One safety solution to provide an additional measure of safety is to equip air braked vehicles with "Long Stroke" air chambers. These chambers typically have ½" of additional push rod stroke allowing an additional margin of safety.

"Long Stroke" chambers are generally marked with a plastic tab identifying them. In the absence of the plastic tab, they often have "LS" or "Long Stroke" embossed in the air chamber body. Square air hose inlet ports provide an additional visual identification of "Long Stoke" air chambers.

Conclusion

CVSA Operation Air Brake data indicates CMVs equipped with ASAs still have a substantially lower number of brake violations than those equipped with manual slack adjusters. The benefits are self evident as the percentage of all CMV brake violations have substantially dropped since the 1992 NTSB Heavy Vehicle Airbrake Performance Safety Study.

It is still unknown what percentage of the relative decrease in violations is due to properly functioning ASAs / ABAs and how many are maintaining adjustment by manually adjusting and over riding the self adjusting mechanism.

It has become apparent there is a general lack of knowledge as to the critical nature of proper installation, lubrication and periodic inspection of these critical safety devices.

It is very important that collision investigators and CMV maintenance personnel be trained and become familiar with the operation and critical factors that can render ASA / ABAs inoperative leading to diminished brake force and/or brake failure.

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