



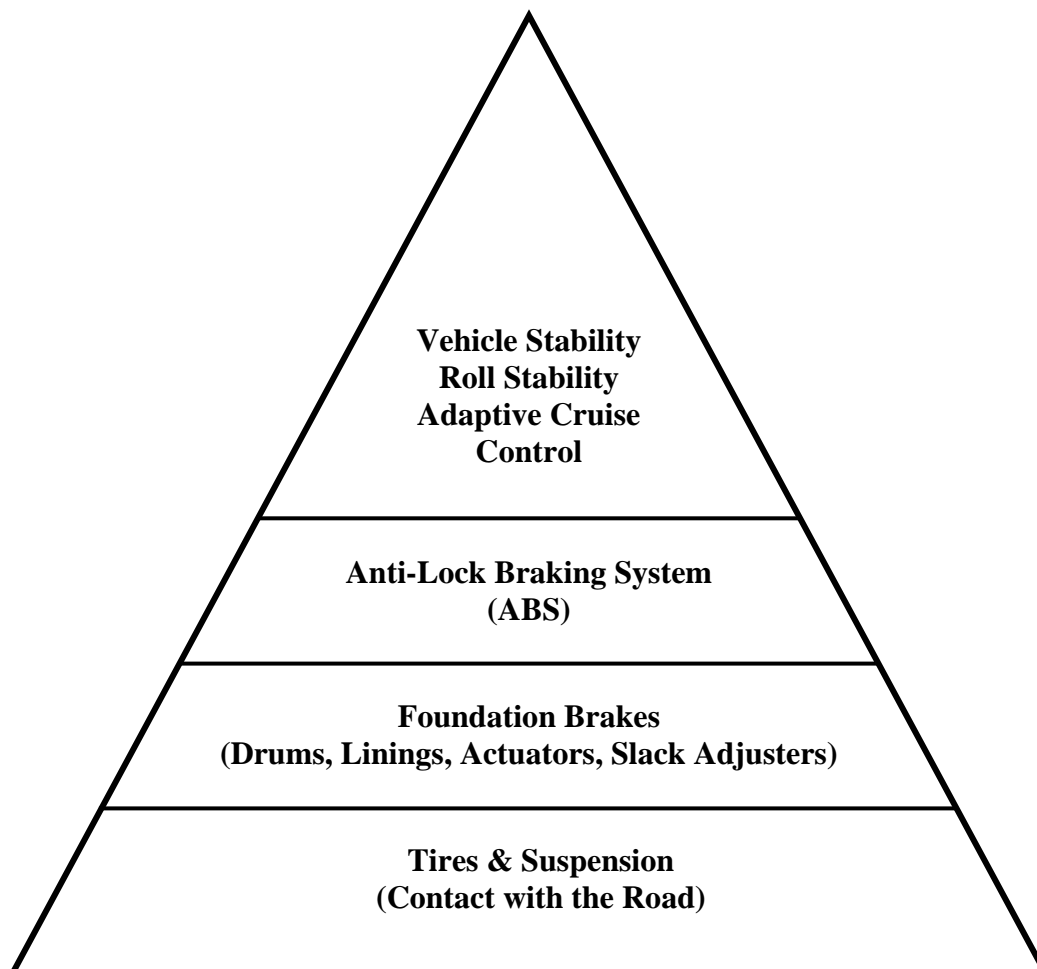
**The Safety Technology Pyramid
Advanced Vehicle Control Systems and their
Dependence on Proper Foundation Brake Performance**

I. Introduction

There has been much written of late concerning the benefits of new safety technologies such as Roll Stability, Yaw Stability, and Adaptive Cruise Control in the commercial vehicle marketplace. While these types of technologies have been embraced and deployed in automotive applications, their development and acceptance into commercial vehicle applications has been typically a slower process.

Currently, there are several Roll Stability, Yaw Stability, and Adaptive Cruise Control (also known as Collision Avoidance) systems on the market for commercial vehicles. These are certainly effective and worthy safety technologies which improve overall vehicle safety and can help to make our roads safer. Often overlooked when examining the benefits of these technologies however; is the impact of proper foundation brake setup and performance on the effectiveness of these advanced vehicle stability systems.

The inter-relation between these technologies can be thought of as the *safety technology pyramid* as shown below.



II. Tires

Tires and their respective contact with the road surface (as part of the vehicle suspension system), are the most critical aspect in vehicle braking and stability. The amount of tire contact with the road and the subsequent coefficient of friction developed at this contact area is critical to overall brake performance as well as vehicle stability. It is well known that if the quality of this contact area is diminished (via badly worn tires, suspension problems, or poor quality road surfaces covered with ice or snow for example), then overall vehicle braking and stability is drastically affected. The quality of this area of contact can also be affected by the tire leaving the road surface due to vehicle instability or roll-over conditions.

III. Foundation Brakes

Second to (and also fully dependent upon) tire contact with the road surface, is the braking system of the vehicle. The brake system slows the vehicle by applying a braking force at each wheel end, but can only stop the vehicle based upon the coefficient of friction and the amount of surface area contact between the tire and the road. When this area of contact is optimum (good surface area contact and a high coefficient of friction) the braking system can work at optimum performance. When this contact is diminished, then of course the ability of the braking system to stop the vehicle is reduced and overall vehicle stability is diminished as well.

Most commercial vehicles in the U.S. utilize air-brake systems which convert air-pressure into a mechanical braking force. Also, most commercial air-braked vehicles in the U.S. utilize drum brakes (linings inside a brake drum that are pushed into the drum by mechanical force). These typical air-brake systems utilize an air-brake actuator (or chamber), along with a slack adjuster and an s-cam which drives the drum linings into the brake drum during a brake event. When equipped with these types of braking systems, the vehicle's brake actuator stroke must be monitored and maintained in order to ensure that the braking system is operating properly. If the brake actuator stroke is not in the proper operating range, then the braking system is either in need of repair or in need of adjustment. Brake actuator stroke measurement is the only reliable indicator that the air brake system is in adjustment and in proper working condition. **Therefore, it is critical that the brake actuator stroke on these air-brake systems be properly set and maintained in order to ensure optimum brake performance and operation.**

IV. Anti-Lock Braking Systems (ABS)

Anti-lock Braking Systems (ABS) were a further development of safety technology that fully depends on both the tire contact with the road, as well as the optimum performance of the foundation brake system, in order to operate effectively. ABS systems control the wheel slip during a braking event by modulating the brake pressure applied at each wheel

in order to prevent wheel lock-up. This is important because when a wheel experiences lock-up, then static friction is converted into sliding friction and the overall coefficient of friction drops, increasing stopping distances. ABS can (when used with properly functioning tires, suspension, and foundation brake systems) reduce stopping distances by preventing wheel lock-up during brake events.

Another significant advantage of ABS systems is that by preventing wheel lock-up, the driver can continue to steer the vehicle through a braking event. When the front wheels of a vehicle lock-up, then maneuverability is lost and the driver cannot steer the vehicle through the braking event.

When however, foundation brakes are inoperative or out-of-adjustment, the ABS system cannot operate as effectively since the brakes may not be able to create enough force to reach wheel lock-up. With full brake force unavailable at one or several wheel ends, the ABS system will not be able to modulate the wheels close to the lock-up point and obtain maximum braking. Also, vehicle instability can be introduced by the braking system if one side of an axle has full brake force and the other side has limited brake force. This introduces a “yaw” moment (or turning motion) into the vehicle and can cause the vehicle to spin or turn unintentionally.

V. Roll Stability Systems

Roll Stability Systems build upon the tires, suspension, foundation brakes, and ABS systems in order to reduce the potential of a roll-over in certain tractor-trailer situations. The Roll Stability System utilizes a “lateral accelerometer” in order to sense when the vehicle is becoming unstable in a turn. Once the system detects that a dangerous lateral acceleration has been detected (i.e. a possible roll-over is imminent), then the system will typically apply the tractor drive axle brakes and the trailer brakes while reducing engine torque in order to slow and stabilize the vehicle. In order for the Roll Stability system to function properly, the foundation braking system must be operational and in proper adjustment. While Roll Stability systems have some built in safety margin, the effectiveness of the system is reduced in relation to the number of brakes that are out of adjustment. If one brake is out of adjustment the effect will be minimized, but if more brakes are out of adjustment then the effect quickly becomes more severe. In the end, the system will only be fully effective if the foundation brake system is operating properly and to its full potential.

VI. Yaw Stability Systems (Full Stability Control)

Yaw Stability Systems (also known as Full Stability Control Systems) go another step beyond Roll Stability by not only intervening in potential roll-over situations, but by intervening in under-steer, over-steer or other dangerous dynamic situations. The Yaw Stability Systems accomplish this by monitoring “yaw” (the amount of vehicle turning moment being realized) and comparing it to the position of the steering wheel (sensed by

a steering wheel angle sensor). If the system detects an over-steer situation, the system will typically brake the outside front wheel and reduce engine torque in order to attempt to correct the vehicles trajectory. In an under-steer situation, typically the inside front wheel brake is independently applied while reducing engine torque. Also, during other dynamic situations, the system may brake several or all of the wheels at varying amounts while reducing engine torque in order to keep the vehicle stable. One can readily see that if the front axle brakes are out-of-adjustment, then the effectiveness of the system is greatly reduced. This also applies to the remaining brakes on the vehicle since they all are used individually, or in combination, to control the overall stability of the vehicle. Once again, the proper adjustment and operation of the foundation brake system is critical to Yaw Stability system operation and performance.

VII. Adaptive Cruise Control Systems (Collision Avoidance)

Adaptive Cruise Control Systems (also know as Collision Avoidance Systems) are used to control the driving distance between vehicles and help to maintain proper (and safe) following distances. These systems often utilize radar to determine the distance from the subject vehicle to the next vehicle further ahead on the road. The system calculates the actual distance between the vehicles and then adjusts vehicle speed, and / or applies the vehicles brake system in order to maintain a safe driving distance based on the driving speed of the subject vehicles. These systems are automatic and require no driver intervention to maintain safe driving distances. These systems do however heavily rely on proper brake performance in order for these systems to operate effectively. Again, if the vehicle brakes are out-of-adjustment, then the proper intervention may not be possible. Also, if the brakes are out-of adjustment and the Adaptive Cruise Control engages, the vehicle can become unstable (pull to one side for example) if some of the vehicle brakes are severely out-of-adjustment or non-functioning.

VIII. Summary

It can be seen from the explanation of the various technologies, that all depend upon proper brake adjustment in order to be effective. *This makes it critical that brake actuator stroke is closely monitored, and foundation brake issues corrected, if these dependent technologies are to perform at their full potential.* Constant monitoring of brake chamber stroke can provide early warning of pending brake system issues, thus allowing foundation brake problems to be addressed *before* the system is called upon to intervene by other advanced safety technologies in a dangerous driving situation.