



# CRANE CO. Hydro-Aire Inc. Antiskid Tutorial

June, 2000



**Hydro-Aire Inc.,  
3000 Winona Avenue  
Burbank, CA 91504  
(818) 526-2600**

[www.hydroaire.com](http://www.hydroaire.com)



## ANTISKID TUTORIAL

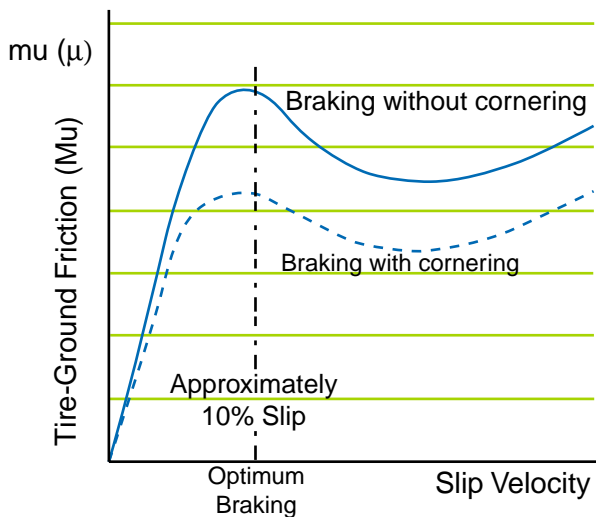
### ANTISKID SYSTEM OPERATION

When brake force is applied to a vehicle wheel that is in normal contact with the pavement, the rubber of the tire begins to stretch in response to friction heating and the force applied at the interface between the tire and the pavement. This has the effect of making the tire circumference significantly larger than it is without the brakes applied.

If the speeds of two identical wheels running side by side on a common axle are compared, one equipped with a brake and the other without, this phenomenon can be readily observed.

When the brake force is applied, the angular velocity of the braked wheel drops by several percent. Early researchers thought that this slowing down was the result of the tire slipping against the pavement and coined the term "slip velocity" to express the difference between the circumferential speeds of the braked and un-braked wheels. If the level of braking is increased until the coefficient of friction,  $\mu$ , can no longer support the force being applied to the rubber, then true slip begins and the available stopping force begins to diminish. This is shown in the mu-slip curve illustrated in **Figure 1**.

Figure 1, Mu-Slip Curve



Operation at the peak of the mu-slip curve gives the highest braking efficiency. Research suggests that a small level of true slip may increase  $\mu$  and that the peak of the curve actually occurs after true slip has begun. Operation just beyond the peak of

the curve results in increased tire wear and if the brake is applied harder still, a skid develops that may lock the wheel and blow the tire if unchecked.

Modern Hydro-Aire antiskid brake control systems work by measuring the speed of the wheel to determine slip and adjusting the brake pressure to keep the tire operating at the peak of the mu-slip curve. A rotary transducer, which is usually mounted in the end of the aircraft axle, measures wheelspeed and provides a signal to an electronic brake control unit (BCU). The control unit derives where on the mu-slip curve the tire is operating for the prevailing runway conditions and sends a correction signal to the antiskid valve as required.

In a conventional brake system, the pilot applies brake pressure through a brake metering valve that is connected to the brake pedals by a mechanical cable and pulley system, or through a hydraulic servo system. An electrically controlled antiskid valve is placed between the brake metering valve and the brake piston housing. When the pilot applies brake pressure at a level below that required to skid the tire, the antiskid valve ports full flow to the brake. If the metered pressure exceeds skid level, then the antiskid valve modulates the metered pressure by dumping pressure to the return side of the hydraulic system to maintain performance at the peak of the mu-slip curve.

In the Mark V brake-by-wire system, the mechanical cable system between the pedals and the metering valve is replaced by an electrical transducer at the brake pedal that provides position input to the brake control electronic unit. The position of the pedal is sensed by the control unit, which generates a command to an electrical pressure valve that replaces the mechanical metering valve. In this arrangement, the same valve performs both the pressure application and antiskid functions. Braking efficiencies as high as 98% have consistently been recorded using the Mark V system.

### Antiskid Control Loop

The Hydro-Aire antiskid system implementation includes an axle mounted wheelspeed transducer driven by a drive coupling from the wheel hubcap. The Hydro-Aire wheelspeed transducer provides a sinusoidal output signal with a frequency directly proportional to wheel rotational velocity and affords significant EMI immunity. The basic, closed loop, antiskid control function is illustrated

- **Phase Compensation** - The Phase Compensation function ( $K \frac{de}{dt}$ ) provides a small-signal compensation for brake system hydraulic phase-lag.

The three elements are summed to produce a composite signal that drives the antiskid control valve.

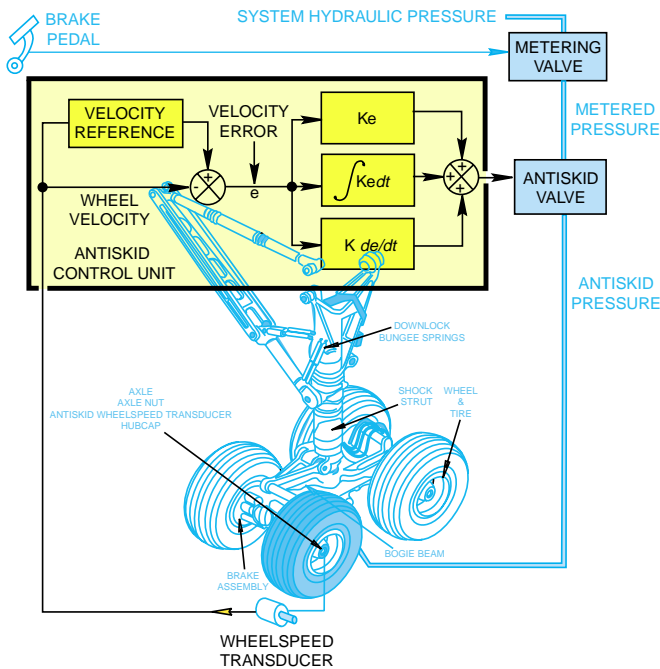


Figure 2, Antiskid Control Loop

in Figure 2.

The wheelspeed signal is input to the antiskid control unit where it is processed to produce a wheel velocity signal. The wheel velocity signal initializes Velocity Reference when “slip” velocity is zero (no braking force applied). The subsequent difference between Wheel Velocity and reference Velocity is Velocity Error ( $e$ ), which contains slip velocity information.

The velocity error signal is input to three control elements:

- **PBM**-The pressure bias modulation function is a time integral of error ( $K_e dt$ ) which produces a slowly changing average pressure level to maintain brake pressure at a level that maintains slip near the optimum level.
- **Transient Control**-The Transient Control function ( $K_e$ ) provides a rapid and large scale adjustment to brake pressure when the velocity error is too large, indicating the onset of excess slip.

## ANTISKID SYSTEM FEATURES

### Basic Antiskid Operation

The basic antiskid function improves (reduces) aircraft stopping distance and increases available cornering force under the most severe runway conditions by maintaining wheel slip at or very near, the peak of the available  $\mu$ -slip curve.

For a given pavement condition, a tire is capable of producing a fixed amount of friction force. This force must be divided between slowing the aircraft and reacting to lateral forces to maintain directional control. The more force that is left over once an acceptable level of aircraft deceleration has been reached, the more cornering capability can be achieved. The use of antiskid to provide high operating efficiency maximizes cornering capability. This is also illustrated in Figure 1.

### Touchdown Protection

The touchdown protection feature prevents the pilot from inadvertently landing the aircraft with brakes applied. The brakes are maintained in a released condition until the aircraft has touched down and the wheels have spun up.

### Hydroplane Protection

Hydroplane protection enhances system performance on icy or flooded runways or when landing gear vertical load is extremely light. Wheel speed is compared to the inertial reference groundspeed of the aircraft (when available) as an additional safeguard.

### Locked Wheel Protection

Locked wheel protection compares the speed of a wheel against the other wheel(s) on the aircraft. With a typical threshold of 30% (70% speed difference), Locked Wheel Protection will release the



wheel that has entered a deep skid condition and is an additional safety feature.

---

### Built-in-Test (BIT)

Modern antiskid systems are equipped with user friendly system fault detection and self-diagnostic systems that provide flight crews with necessary system indications and assist ground crews during system troubleshooting.

---

### Antiskid System Components

The components that are combined to produce a modern, adaptable, high efficiency brake control system are illustrated in Figure 3, Figure 4, Figure 5. and Figure 6.

Figure 3, Electronic Brake System Control Unit

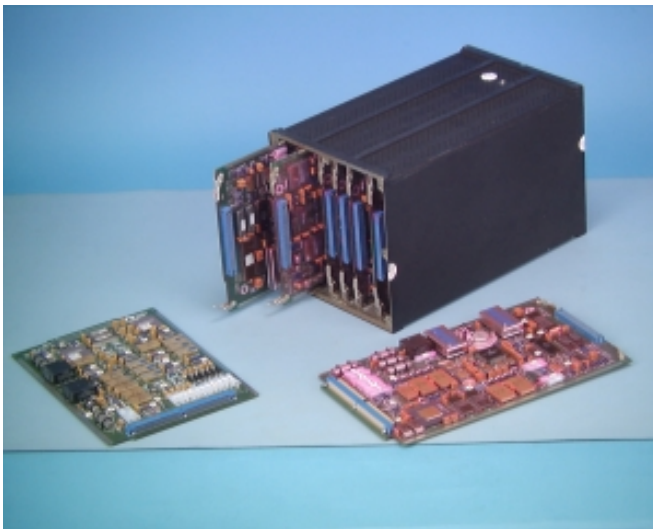


Figure 4, Wheelspeed Transducer

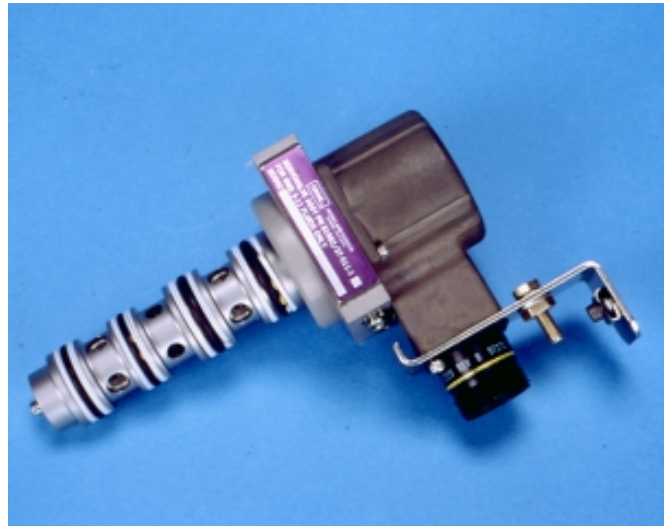


Figure 5, Cartridge Antiskid Control Valve

Figure 6, Six Valve Manifold Assembly

