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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE RECOMMENDED PRACTICE

SAE ARP1907 REV. A

Issued 1988-06
Revised 2001-12

Superseding ARP1907

Automatic Braking Systems Requirements

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1. SCOPE:

This ARP covers the functional, design, construction, and test requirements for Automatic Braking Systems. Installation information and lessons learned are also included.

1.1 Purpose:

This Aerospace Recommended Practice (ARP) recommends minimum requirements for Automatic Braking Systems (ABS)

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP490E	Electrohydraulic Flow-Control Servovalves
ARP1070B	Design and Testing of Antiskid Brake Control Systems for Total Aircraft Compatibility
ARP5988B	The Determination of Particulate Contamination in Liquids by the Particle Count Method
ARP926B	Fault/Failure Analysis Procedure
ARP1383A	Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers and Similar Fluid System Components
ARP4102	Core Document Flight Deck Panels, Controls, and Displays
ARP4102/2	Automatic Braking System (ABS)
ARP4102/4	Flight Deck Alerting System (FAS)
AS4059C	Aerospace Fluid Power – Cleanliness Classification for Hydraulic Fluids
AS8775	Hydraulic System Components, Aircraft and Missiles, General Specification for

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-810C - Environmental Test Methods

Federal Aviation Regulations, Part 25, Airworthiness Standards: Transport Category Airplanes

FAA Advisory Circular AC 25.1309-1A - System Design and Analysis, dated June 21, 1988

FAA Advisory Circular AC 25-7A - Flight Test Guide for Certification of Transport Category Airplanes, March 31, 1998

2.1.3 Commercial Standards:

ARINC 404	Air Transport Equipment Cases and Racking
ARINC 413	Aircraft Electrical Power Utilization and Transient Protection
ARINC 600	Air Transport Avionics Equipment Interfaces
RTCA DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA DO-178B	Software Considerations in Airborne Systems and Equipment Certification
NAS 1638	Cleanliness Requirements of Parts Used in Hydraulic Systems

3. DESCRIPTION:

The ABS is used at the pilot's option to initiate controlled ground braking automatically in either a landing or takeoff mode for the following benefits:

a. Improved safety through consistent early brake application.
b. Improved safety through immediate full pressure braking during a rejected takeoff (RTO) condition.
c. Increased passenger comfort through controlled deceleration and smooth brake pressure application and release.
d. Reduced pilot workload.

A functional diagram of a typical ABS control system is shown in Figure 1. The major ABS units are the control panel, electronic control unit (box/board), hydraulic module, and shuttle valves.

3. (Continued):

The system is armed by the pilot, either on the ground prior to take-off or in the air prior to landing. The ability to arm the system (apply power, and pre-set for operation) is made contingent upon certain occurrences and specific inputs from other aircraft systems. The application and automatic control of brake pressure thereafter, to achieve a deceleration level pre-selected by the pilot, similarly depends on the same or additional inputs, or both, from other systems. The ABS control circuitry receives aircraft deceleration from a linear accelerometer unit (preferred) or from wheel speed transducers, for comparison with the pilot selected deceleration, and then supplies a control signal to a valve, which applies pressure to the brakes. The system may use an individual control valve between the hydraulic supply and each brake, which serves the brake control, antiskid, and ABS functions; or it may incorporate a separate control valve that bypasses pressure around the pilot metering valves to all brakes as shown in Figure 1. The disarming of the system (removal of power from controlling functions) is accomplished automatically by normal pilot procedures, fault detection, or manually by the pilot if he desires.

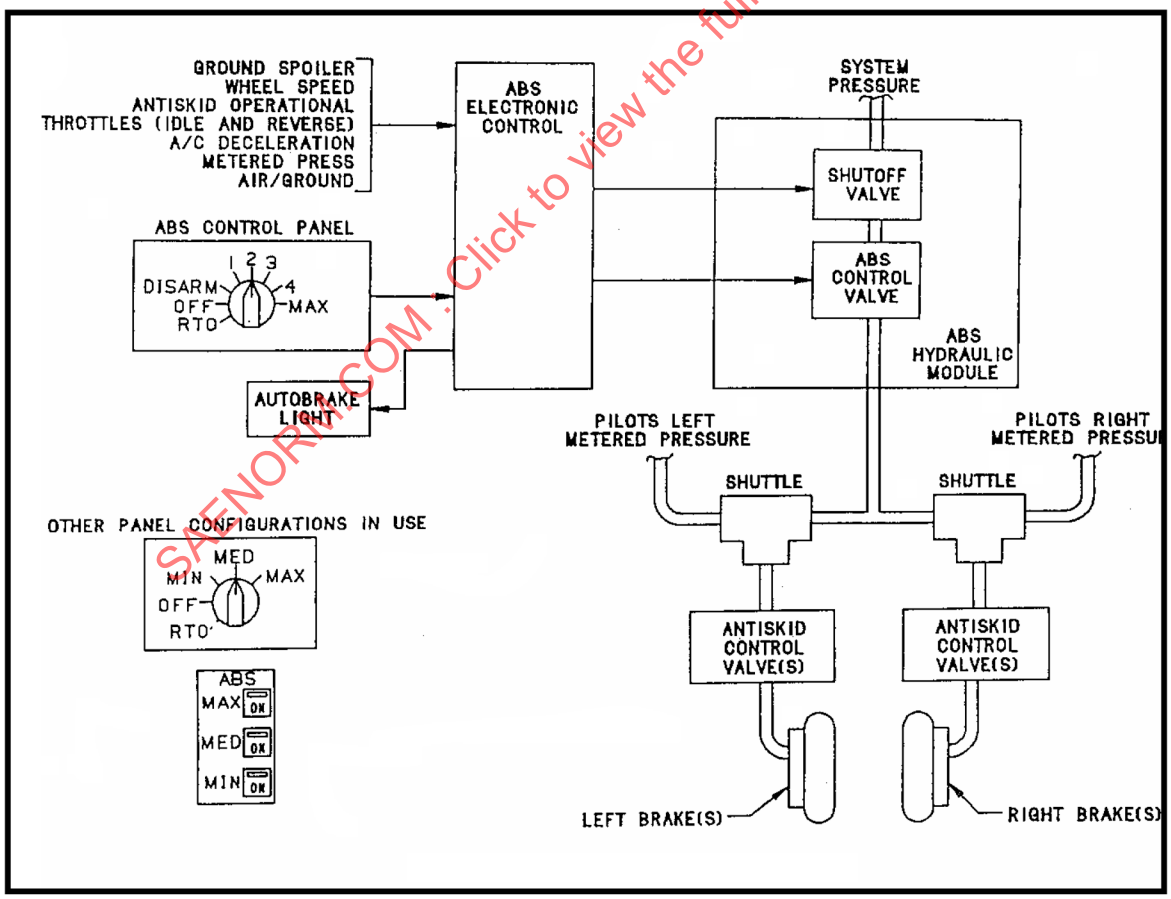

FIGURE 1 - Typical ABS Functional Diagram

4. REQUIREMENTS:

These design requirements are for landing and rejected take-off (RTO) automatic braking systems designed as backup systems and not for systems designed for use as the primary braking means (that is, certification performance basis). Systems designed for primary use must incorporate additional requirements related to insuring a high reliability of system operation during normal, adverse, and failure conditions.

4.1 Functional:

4.1.1 General:

a. The ABS should be a pilot-selectable feature that automatically applies RTO or landing brakes without a pilot pedal input.
b. The ABS braking should be applied equally to all brakes.
c. The ABS should not interfere with the pilot's ability to take over normal braking by application of his brake pedal(s).
d. The ABS should not adversely affect antiskid system operation under any conditions, and should not apply braking unless the antiskid is ON and fault free.
e. A failure of other automatic stopping means (for example, auto spoilers and auto reversers) should not prevent the ABS from operating.
f. Flight deck controls, procedures, and annunciations should be as simple as possible and should be the same for both landing and RTO. An acceptable flight deck configuration is a single switch for both landing and RTO, and a single “AUTOBRAKES” indication to indicate system disarm.
g. For landing, the ABS should be designed to smoothly apply the brakes as soon as possible after touchdown and to smoothly control the braking to maintain a constant overall aircraft deceleration as selected by the pilot.
h. The ABS should modulate braking to maintain the selected deceleration level and to compensate for other decelerating forces such as, spoilers, reverse thrust, and aerodynamic drag.
i. Brake application should not be dependent on nose gear touchdown; however, careful consideration should be given to the initial brake application to ensure a controlled and smooth nose gear touchdown.
j. When landing at high sink speeds on rough surfaces, special consideration should be given to systems that ensure non-critical loading of the nose gear under the most adverse combination of bump location and braking.
k. ABS braking modulation should be smooth at all times to ensure passenger comfort.
l. The pilot should be capable of changing the deceleration level at any time.
m. The ABS should be capable of operating to a full stop.
n. For RTO, the ABS should be designed to apply immediate full braking upon throttle cut for a high speed RTO and should be capable of operating to a full stop.
o. The system design should be simple, reliable, and require minimum maintenance. The system operation should be tolerant of crew mis-procedures.

4.1.1 (Continued):

p. Each item of installed equipment should meet the functional and installation requirements of FAR 25.1301, 1307, 1309, 1316, and 1322 and satisfy the guidance of FAA AC 25-1309-1A, and the automatic braking system should perform to meet the requirements of FAR 25.101 (f) and (h).
q. A failure of any component of the ABS which renders the ABS inoperable or degraded should be indicated to the pilots in compliance with FAR 25.1322.

4.1.2 Flight Deck Configuration: An example of an acceptable flight deck configuration in present use is shown in Figure 1 and consists of a single, magnetic latching, rotary switch and a single "AUTOBRAKE" light. The design of flight deck configurations should comply to ARP4102 and ARP4102/2.

4.1.2.1 Selector Switch:

a. A single crew action should be required to select the ABS for the landing or RTO mode.
b. The landing mode should be capable of being armed (or changing the selected deceleration level) at any time during cruise, descent, approach, or landing rollout.
c. The landing mode should not be capable of being armed during takeoff.
d. Arming of the RTO mode should be possible at any time the aircraft is on the ground, including at the ramp, during taxi out, or during takeoff.
e. Arming of the RTO mode should not be possible prior to landing.
f. In the landing mode, the switch should latch in the armed position and remain latched until a disarm requirement occurs (in which case the switch automatically drops to the DISARM position).
g. In the RTO mode, the switch should remain latched until the aircraft lifts off (in which case the switch automatically drops to the OFF position).
h. The switch should be readily accessible to both pilots.

4.1.2.2 Flight Deck Indication:

a. The AUTOBRAKE indication should come on only to indicate that the ABS (landing or RTO) has disarmed. A possible exception to this is that, when the switch is placed in the OFF position, the light may come on (after a 3 s delay) to indicate a system failure that could cause uncommanded application of the brakes. An example would be that the ABS shutoff valve is open (as sensed by a pressure switch downstream of the valve). When the RTO mode is selected, the indication should not come on during taxi, takeoff, or low speed RTOs and should come on only if ABS RTO braking is not applied after a high speed RTO is initiated.
b. The AUTOBRAKE indication should be in plain view of the crew during the landing and rollout, and should be designed in accordance with ARP4102/4.
c. Once the AUTOBRAKE light has come on, the ABS pressure should be released and the light should remain on until the selector switch is positioned to OFF:

4.1.3 Landing ABS Operating Logic:

4.1.3.1 Arming (Landing): The selector switch should latch in a selected landing position (e.g. 1, 2, 3, 4, or MAX) when all of the following conditions are met:

a. Deceleration level manually selected,
   and
b. No disarm condition exists.

Once armed, the switch should remain latched in the selected position and the AUTOBRAKE indication should remain extinguished until a disarm condition occurs or until the switch is manually positioned to OFF. The AUTOBRAKE indication should reflect the state of the system, not the position of the switch. Disarm by thrust lever should not be possible until after ABS operation has begun following touchdown.

4.1.3.2 Application (Landing): When armed, the system should smoothly and promptly apply brakes to the selected level of deceleration when all of the following conditions are met:

a. Thrust levers retarded to idle,
   and
b. airplane on ground,
   and
c. wheels spun up on the aircraft.

The ABS should continue to brake until a disarm condition occurs or until the selector switch is manually positioned to OFF. The use of reverse thrust should not disarm or have any adverse effect on the operation of the ABS.

4.1.3.3 Disarm (Landing): The ABS should disarm when any of the following conditions are met:

a. Either brake pedal is applied above a preset landing ABS braking level,
   or
b. any thrust lever is advanced while on the ground after touchdown (except that, during the first few seconds after the touchdown air-to-ground transition, it may be desirable that an advanced thrust lever will not cause a disarm; and, if thrust levers are advanced for thrust reverse, it should not cause a disarm),
   or
c. ground spoilers are stowed, after having been deployed on the ground,
   or
d. An ABS fault is detected (such as failure to apply ABS pressure when the aircraft deceleration is below the selected level),
   or
e. The antiskid system is OFF or an antiskid fault is detected.

4.1.3.3 (Continued):

When disarmed, the ABS braking command should be promptly, but smoothly, removed, the AUTOBRAKE indication should illuminate, and the switch should unlatch and fall to the DISARM position. Once disarmed, the system should remain disarmed until manually re-armed or selected OFF.

4.1.3.4 Off (Landing): The system should immediately release ABS braking (if on) and extinguish the AUTOBRAKE indication (if turned on) when the following condition is met:

a. Switch is manually selected OFF.

When the switch is off, the AUTOBRAKE indication should remain extinguished except to indicate an ABS fault that could result in uncommanded brake application.

4.1.4 RTO ABS Operating Logic:

4.1.4.1 Arming (RTO): The selector switch should latch in the RTO position when all of the following conditions are met:

a. RTO is manually selected,
   and
b. airplane is on ground
   and
c. no ABS faults are detected,
   and
d. antiskid system in ON and no faults are detected (further consideration should be given to this requirement on installations where the antiskid is shut off for taxi).

Once armed, the switch should remain latched in the RTO position until an OFF condition occurs. The AUTOBRAKE indication should remain extinguished until a DISARM (RTO) condition occurs (consideration should be given to the indication during the taxi and takeoff roll in regard to the advisability of alerting the pilot of antiskid/ABS faults during this critical time period).

4.1.4.2 Application (RTO): When armed, the ABS system should immediately apply full braking when all the following conditions are met

a. All thrust levers are advanced when airplane is accelerated through a predetermined ground speed (60 to 100 KTS typical),
   and
b. ground speed is above the predetermined level,
   and
c. all thrust levers are retarded after reaching the predetermined speed

Once applied, RTO automatic braking should continue until a DISARM (RTO) condition occurs or until the switch is positioned OFF.

4.1.4.2 (Continued):

Consideration should be given to applying less than full automatic braking with the nose gear in the air, to prevent hard nose slam-down for RTOs after rotation but before liftoff.

The use of reverse thrust should not disarm or have any adverse effect on the operation of the ABS.

4.1.4.3 Disarm (RTO): The ABS should disarm when the following conditions are met:

An RTO has been initiated above a predetermined ground speed (as determined by logic redundant to the application logic),

and

a. either brake pedal is applied above a preset RTO pressure level,
   or
b. any thrust lever is advanced while on the ground (except that, if thrust levers are advanced for thrust reverse, it should not cause a disarm),
   or
c. ground spoilers are stowed, after having been deployed (on the ground),
   or
d. An ABS fault is detected (such as failure to apply full braking),
   or
e. antiskid OFF or fault.

When disarmed, the ABS braking should be immediately released, the AUTOBRAKE indication should illuminate, and the switch should remain latched in the RTO position. Once disarmed, the system should remain disarmed until manually selected OFF.

4.1.4.4 Off (RTO): The ABS system should immediately release ABS braking (if on), extinguish the AUTOBRAKE indication (if on), and unlatch the switch (allowing it to fall to OFF) when any of the following conditions are met:

a. Switch is manually selected OFF,
   or
b. airplane is airborne.

When the switch is OFF, the AUTOBRAKE indication should remain extinguished except to indicate a fault that could result in uncommanded brake application.

4.1.5 Logic and Control Inputs:

4.1.5.1 Thrust Lever Position:

a. Sensors (or switches) should be installed to monitor the position of each thrust lever. For airplanes with three or less thrust levers, multiple switches should be installed on each thrust lever.
b. The thrust lever position sensors, or other means, should be rigged as close as possible to the hands-off idle position, allowing for reasonable thrust lever position tolerances.
c. The thrust lever position sensors should be configured so that the dominant failure mode indicates thrust levers advanced.
d. Positioning the thrust levers for reverse thrust should not disarm the ABS.

4.1.5.2 Brake Pedal Applications:

a. For the landing mode, pressure switches, or other means, should be installed to indicate when either the left or right braking has been applied above a predetermined level. The level should be high enough to preclude inadvertent system disarm, yet low enough to allow smooth intentional disarm.
b. For the RTO mode, brake pedal application switches should be installed to operate when either brake pedal has been applied to a point near full brake application.
c. The brake pedal application switches should be configured so that the dominant failure mode indicates pedal braking applied.

4.1.5.3 Air/Ground Mode:

a. Position sensors should be installed on the main landing gears to monitor the air/ground mode. These sensors (or their associated logic, or both) should be used for all ABS air/ground logic except for special deceleration control logic to address smooth nose gear derotation. For this function, nose gear air/ground switches or other means such as proximity sensors or inertial reference pitch attitude may be used.
b. The air/ground sensors (or logic, or both) should be configured so that the dominant failure mode indicates ground mode.

4.1.5.4 Ground Speed and/or Wheel Spin-up:

a. At least two independent ground speed or wheel spin-up, or both, signals should be obtained for the separate purposes of providing ABS application logic and fault monitoring logic. Wheel speed signals are preferred due to their inherent accuracy (relative to ground speed) and due to their relationship to the antiskid system (insurance that a speed reference exists for locked wheel protection). Airspeed signals should not be used due to their susceptibility to altitude, temperature, and wind.
b. The ground speed or wheel spin-up, or both, signals should be configured so that their dominant failure mode indicates low speed or no spin-up.

4.1.5.5 Deceleration:

a. At least two independent airplane deceleration signals should be obtained for the separate purposes of providing ABS deceleration control and fault monitoring logic. Signals directly measuring aircraft longitudinal deceleration are preferred to other means of ABS control, such as differentiated wheel speed signals, due to minimal lag/errors by the implementation of the directly measured deceleration system.
b. The deceleration signal(s) should be configured so that their dominant failure mode indicates no deceleration.

4.1.6 Built-in Test Equipment (BITE): BITE provisions for test or maintenance use should be incorporated in the electronic control unit and should meet the following general requirements:

a. The controls and displays should be located on the front panel of the control unit or be incorporated in a central monitoring/maintenance computer system.
b. The BITE provisions, along with simple procedures for conducting the tests, should provide a complete verification of the system integrity and should permit fault isolation to the LRU (Line Replaceable Unit) or input signal. To facilitate maintenance, the fault isolation feature should be designed so that the ABS is powered but need not be armed.
c. Hardware or software added to meet the BITE requirements should not interfere with the normal system functions.
d. The design should have a continuous failure monitoring system which will store continuous and intermittent faults in memory for later readout by ground maintenance personnel.
e. The design should allow control and assessment by one maintenance person.

4.1.7 Failure Modes:

4.1.7.1 Single Failure Conditions: The ABS should be designed so that no single failure condition will:

a. Cause inadvertent ABS brake application during takeoff.
b. Fail to indicate when the system is unable to deliver brake pressure to the selected level.
c. Adversely affect antiskid system operation.
d. Interfere with or prevent pilot pedal braking.
e. Fail to release ABS when pilot pedal braking is applied or when thrust levers are advanced for takeoff.

4.1.7.2 Probable Single Failure Conditions: The ABS should be designed so that no probable single failure condition will:

a. Fail to indicate when the system is unable to deliver RTO ABS braking.
b. Apply ABS landing brakes before landing, or apply ABS RTO braking before an RTO above a predetermined ground speed (for example, during taxi).
c. Cause AUTOBRAKE indication during takeoff.