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AUTOMATIC BRAKING SYSTEMS REQUIREMENTS

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1. PURPOSE:

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

2. SCOPE:

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

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.

(e) Facilitates minimum stopping distance, when required, through early brake application.

An offset against these benefits is increased brake and tire cost which may occur depending on the system design and how it is used by the operator.

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

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 Fig. 1. The disarming of the system (remove power from controlling functions) is accomplished automatically by normal pilot procedures, fault detection, or manually by the pilot if he desires.

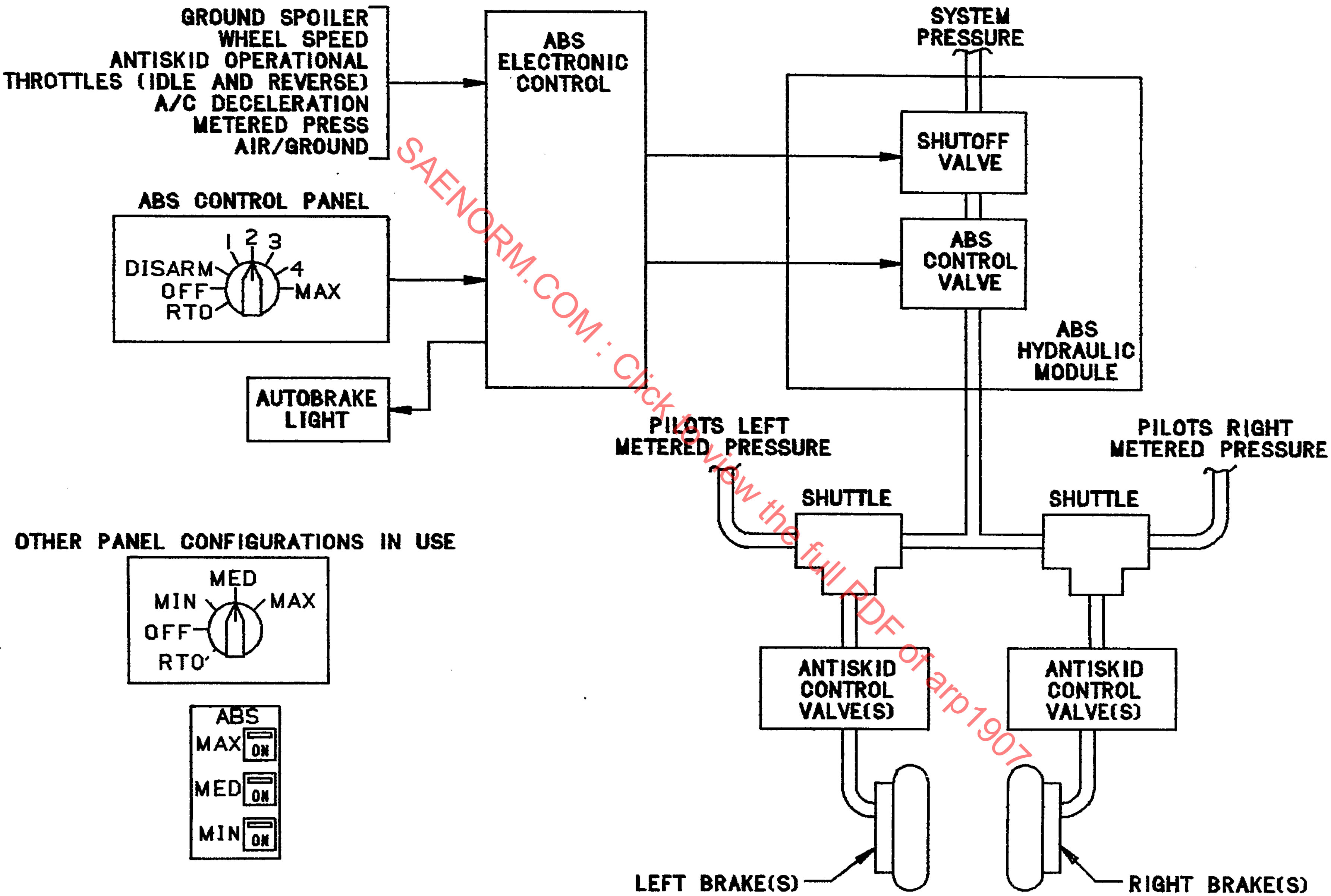

FIGURE 1 - Typical ABS Functional Diagram

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 pressure shall be applied equally to all brakes.

(c) The ABS shall not interfere with the pilot's ability to take over normal braking by application of his brake pedal(s).

(d) The ABS shall not adversely affect antiskid system operation under any conditions, and shall not apply brake pressure 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 annunications 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" light 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. The ABS should modulate brake pressure to maintain the selected deceleration level and to compensate for other decelerating forces such as, spoilers, reverse thrust, and aerodynamic drag. 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. 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. ABS pressure modulation should be smooth at all times to ensure passenger comfort. The pilot should be capable of changing the deceleration level at any time. The ABS shall be capable of operating to a full stop.

4.1.1 (Continued):

(h) For RTO, the ABS shall be designed to apply immediate full braking upon throttle cut for a high speed RTO and shall be capable of operating to a full stop.

(i) The system design should be simple, reliable, and require minimum maintenance. The system operation should be tolerant of crew mis-procedures.

(j) Each item of installed equipment should meet the functional and installation requirements of FAR 25.1301, 1309, and perform per FAR 25.101 (h) (2).

4.1.2 <u>Flight Deck Configuration</u>: An example of an acceptable flight deck configuration in present use is shown in Fig. 1 and consists of a single, magnetic latching, rotary switch and a single "AUTOBRAKE" light. Consideration should be given to ARP4102 and ARP4102/2 in the design of new flight deck configurations.

4.1.2.1 <u>Selector Switch</u>:

(a) A single crew action should be required to select the ABS for the landing or RTO mode. 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. The landing mode shall not be capable of being armed during takeoff. The RTO mode shall be capable of being armed at any time the aircraft is on the ground, including at the ramp, during taxi out, or during takeoff. The RTO mode shall not be capable of being armed prior to landing.

(b) In the landing mode, the switch shall latch in the armed position and remain latched until a disarm requirement occurs (in which case the switch automatically drops to the DISARM position).

(c) In the RTO mode, the switch shall remain latched until the aircraft lifts off (in which case the switch automatically drops to the OFF position).

(d) The switch should be readily accessible to both pilots.

4.1.2.2 <u>Indicator Light</u>:

(a) The AUTOBRAKE light 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 that the ABS shutoff valve is open (as sensed by a pressure switch downstream of the valve). When the RTO mode is selected, the light 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.

4.1.2.2 (Continued):

(b) The AUTOBRAKE light 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 shall be released and the light shall 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 shall latch in a selected landing position (that is, 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 shall remain latched in the selected position and the AUTOBRAKE light shall remain extinguished until a disarm condition occurs or until the switch is manually positioned to OFF. Disarm by thrust lever shall not be possible until after ABS operation has begun following touchdown.

4.1.3.2 Application (Landing): When armed, the system shall 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 shall continue to brake until a disarm condition occurs or until the selector switch is manually positioned to OFF.

The use of reverse thrust shall 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 pressure 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 shall not cause a disarm),
or

4.1.3.3 (Continued):

(c) ground spoilers are stowed, after having been deployed on the ground,

or

(d) ABS fault detected (such as failure to apply ABS pressure when the aircraft deceleration is below the selected level),

or

(e) antiskid OFF or fault.

When disarmed, the ABS pressure shall promptly, but smoothly, release, the AUTOBRAKE light shall illuminate, and the switch shall unlatch and fall to the DISARM position. Once disarmed, the system shall remain disarmed until manually re-armed or selected OFF.

4.1.3.4 Off (Landing): The system shall immediately release ABS pressure (if on) and extinguish the AUTOBRAKE light (if turned on) when the following condition is met:

(a) Switch is manually selected OFF.

When the switch is off, the AUTOBRAKE light shall remain extinguished except to indicate an open ABS shutoff valve.

4.1.4 RTO ABS Operating Logic:

4.1.4.1 Arming (RTO): The selector switch shall 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 ON and no fault (further consideration should be given to this requirement on installations where the antiskid is shut off for taxi).

Once armed, the switch shall remain latched in the RTO position until an OFF (RTO) condition occurs. The AUTOBRAKE light shall remain extinguished until a DISARM (RTO) condition occurs (consideration should be given to the light operation 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 shall immediately apply full brake pressure when all the following conditions are met:

(a) All thrust levers are advanced when airplane is accelerated through a predetermined groundspeed (60 to 100 KTS typical),

and

(b) groundspeed is above the predetermined level,

and

(c) all thrust levers are retarded after reaching the predetermined speed.

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

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 shall not disarm or have any adverse effect on the operation of the ABS.

4.1.4.3 Disarm (RTO): The ABS shall 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 shall not cause a disarm),

or

(c) ground spoilers are stowed, after having been deployed (on the ground),

or

(d) ABS fault is detected (such as failure to apply full pressure),

or

(e) antiskid OFF or fault.

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

4.1.4.4 Off (RTO): The ABS system shall immediately release ABS pressure (if on), extinguish the AUTOBRAKE light (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 light should remain extinguished except to indicate an open ABS shutoff valve.

4.1.5 Logic and Control Inputs:

4.1.5.1 Thrust Lever Position:

(a) 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 switches, or other means, should be rigged as close as possible to the hands-off idle position.

(c) The thrust lever position switches should be configured so that the dominant failure mode indicates thrust levers advanced.

(d) Positioning the thrust levers for reverse thrust shall 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 pilot metered pressure 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 position switches or metered pressure switches should be installed to operate when either brake pedal has been applied to a point near full brake pressure 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) Switches should be installed on the main landing gears to monitor the air/ground mode. These switches (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 which nose gear air/ground switches may be used.

(b) The air/ground switches (or logic, or both) should be configured so that the dominant failure mode indicates ground mode.

4.1.5.4 Groundspeed and/or Wheel Spinup:

(a) At least two independent groundspeed or wheel spinup, or both, signals should be obtained for the separate purposes of providing ABS application logic and fault monitoring logic. Wheelspeed signals are preferred due to their inherent accuracy (relative to groundspeed) 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 groundspeed or wheel spinup, or both, signals should be configured so that their dominant failure mode indicates low speed or no spinup.

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 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 is not required to be armed.

4.1.6 (Continued):

(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 enable control and assessment by one maintenance person.

4.1.7 Failure Modes:

4.1.7.1 Single Failure Conditions: The ABS shall 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 under any conditions.

(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 shall be designed so that no probable single failure condition will:

(a) Fail to indicate when the system is unable to deliver RTO ABS pressure.

(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 turn-on of the AUTOBRAKE light during takeoff.

4.1.7.3 ABS on Takeoff: No combination of failures, not shown to be extremely improbable, shall result in inadvertent ABS application during high speed takeoff.

Detection of latent hydraulic failures (for example, ABS shutoff valve open) should not rely on the ABS control box being installed.

4.1.8 Status Indications:

4.1.8.1 Armed/Disarmed: This should be an indication of readiness which should include readiness of the ABS together with all supportive systems such as antiskid, accelerometer, thrust lever switches, etc. It should be a visual display located in plain view of the crew which gives a clear indication of the ABS status.

4.1.8.2 Fault: This should indicate a condition of failure of a part of the ABS itself. It should be shown on the aircraft's Integrated Flight Deck Alerting System in accordance with ARP4102/4.

4.2 Design and Construction:

4.2.1 Electrical Requirements - General:

4.2.1.1 Power: The system should be designed to operate satisfactorily from aircraft power having the characteristics of MIL-STD-704 and ARINC 413.

4.2.1.2 Insulation: The resistance between mutually insulated parts should be at least 20 megohms at 500 VDC. The dielectric withstanding voltage for equipment rated over 50 V should be 1500 VRMS, 60 Hz. For equipment under 50 V the withstanding voltage should be 500 VRMS.

4.2.1.3 Bonding: Electrical and electronic units should have a case ground pin in the connector. All conductive surfaces of the case should be bonded such that the DC resistance between the case ground pin and any point on the case does not exceed 0.011 ohms.

4.2.1.4 Connectors: Connectors should be environment resisting type. In high vibration areas, the connectors should be the threaded type with lock wire. The larger pin sizes should be used wherever possible and the maximum spacing maintained between pins. Spare pins shoud be located as near to the outer portion of the plugs and receptacles as practicable.

4.2.1.5 Electromagnetic Interference (EMI): The system should be designed to be electromagnetically compatible with the associated aircraft, its subsystems, and the operational environment.

4.2.1.6 Failure Mode and Effects Analysis (FMEA): During the design phase, the FMEA should be made for the control circuitry and system to ensure that safety requirements are met.

The design of equipment, systems, and installations should meet the requirements of FAR 25.1309. The analysis of failures should be in accordance with the procedures of ARP 926A.

4.2.1.7 Embedded Software: ABS control and BITE software should conform to the standards of RTCA/DO-178A.

4.2.2 Hydraulic Requirements - General:

4.2.2.1 Fluid: Hydraulic units should operate satisfactorily with the specified hydraulic fluid, filtered and controlled to a contamination level of appropriate class per NAS 1638. All testing should be accomplished with the specified operating fluid.

Hydraulic systems using flammable fluid should meet the applicable requirements of FAR 25.863, 25.1183, 25.1185, and 25.1189.

4.2.2.2 Fluid Temperatures: Hydraulic units should operate with fluids in the required temperature range. Unless specified, operating temperature should range from -65°F (-54°C) to 225°F (107°C).

4.2.2.3 Pressure Ratings: Hydraulic units should function satisfactorily over the full range of aircraft supply pressure and return line pressure.

4.2.3 Electronic Control:

4.2.3.1 Construction: The electronic control units should be designed in accordance with MIL-E-5400. To facilitate maintenance, the unit should employ modular plug-in circuit board construction to the maximum extent practical. Circuit boards should be keyed to prevent incorrect insertion of non-interchangeable boards. Board edge type connectors should not be used.

4.2.3.2 Mounting: When electronic equipment racks are available, mounting and hold-down should conform to ARNIC 404 or 600 as required.

4.2.3.3 Cooling: No special cooling arrangements should be required.

4.2.3.4 Semiconductor Devices: All semiconductor microcircuits should be screened to MIL-STD-883, Class B. All discrete semiconductors should be selected from MIL-STD-701 when possible. All semiconductors shall be hermetically sealed and no plastic encapsulated semiconductors should be used.

4.2.3.5 Environmental Conditions: The electronic control unit should be capable of withstanding or operating under the following environmental conditions using test methods specified in MIL-STD-810C or RTCA/DO-160B as determined by the Airframe Manufacturer:

Ambient Temperature
Altitude
Humidity
Fungus
Vibration
Dust
Salt Fog
Explosive Atmosphere
Mechanical Shock
Electromagnetic Interference
Voltage Transients

4.2.4 Hydraulic Units:

4.2.4.1 Construction: The hydraulic units should comply with the design and construction requirements of MIL-H-8775 for Type II equipment and FAR 25.1435.

4.2.4.2 Proof Pressure: The unit should be designed to withstand a proof pressure of 1.5 times maximum operating pressure.

4.2.4.3 Burst Pressure: The unit should be designed to withstand a burst pressure of 2.5 times operating pressure.

4.2.4.4 External Leakage: No external leakage shall occur under any operating temperature or pressure conditions.

4.2.4.5 Solenoid Operated Valves: Solenoid-operated control valves should conform to the applicable requirements of MIL-V-7915 or MIL-V-5529. The design of the solenoid should conform to the applicable requirements of MIL-S-4040.

4.2.4.6 Pressure Modulating Valves: Pressure modulating valves should be designed in accordance with the applicable requirements of MIL-V-27162 and ARP490D and should be suitable for the brake control system environment with special emphasis upon contamination tolerance, stability with life and temperature, internal leakage, tolerance to service handling, and moisture sealing.

4.2.4.7 Environmental Conditions: The hydraulic units should be capable of withstanding or operating under the following environmental conditions using test methods specified in MIL-STD-810C or RTCA/DO-160B as determined by the Airfrme Manufacturer:

Ambient Temperature
Temperature Shock
Altitude
Humidity
Fungus
Vibration
Dust
Salt Fog
Explosive Atmosphere
Mechanical Shock
Electromagnetic Interference

4.2.5 Material and Workmanship:

4.2.5.1 Materials: Materials should be consistent with good commercial usage and suitable for the purpose intended. Wherever possible, the design should incorporate military specification parts and materials consistent with long term availability.

4.2.5.1.1 Metals: All metals used in the construction of the ABS should be corrosion resistant unless suitably plated or treated to resist corrosion during stocking and normal service life.

4.2.5.2 Workmanship: Workmanship and finish should be in accordance with high grade aircraft accessory manufacturing practice.

4.2.6 Identification: All major components should be plainly and permanently marked for identification in accordance with MIL-STD-130.

5. QUALIFICATION TEST:

5.1 System Performance Tests: Integrated system level tests should be conducted using production components to verify that the system satisfies all system functional and performance requirements. This testing should cover the entire range of airplane operating conditions and runway conditions so as to minimize the need for tuning on the airplane. These tests should be conducted utilizing a suitable simulator employing analog or digital computers to simulate the aircraft geometry and weight, landing gear characteristics, brake torque, tire characteristics, and runway conditions. The hydraulic system should be mocked-up using real hardware whenever possible.

5.2 Environmental Tests: The majority of the following minimum environmental tests are conducted in accordance with MIL-STD-810C since its procedures and limits are well defined, however, RTCA/DO-160B should be considered for commercial applications. If the actual aircraft environment exceeds the limits specified, the actual aircraft values should be used for test.

5.2.1 High Temperature: All ABS units should be subjected to a high temperature test in accordance with MIL-STD-810C, Method 501.1, Procedure I. The units should be operated for a representative number of flight cycles as described in 5.3.

5.2.2 Low Temperature: All ABS units should be subjected to a low temperature test in accordance with MIL-STD-810C, Method 502.1. The units should be operated for a representative number of flight cycles as described in 5.3.

5.2.3 Temperature Shock: The hydraulic units should be subjected to a temperature-shock test per MIL-STD-810C, Method 503.1.

5.2.4 Altitude: All ABS units should be subjected to an altitude test in accordance with MIL-STD-810C, Method 500.1, Procedure I.

5.2.5 Humidity: All ABS units should be subjected to a humidity test in accordance with MIL-STD-810C, Method 507.1, Procedure I.

5.2.6 Fungus: All ABS units should be subjected to a fungus test in accordance with MIL-STD-810C, Method 508.1, Procedure I, unless documentation is provided which certifies no fungus nutrients are present in the materials used in the design.

5.2.7 Vibration: All ABS units should be subjected to a vibration test in accordance with MIL-STD-810C, Method 514.2. Mounting (mechanical electrical, and hydraulic) should simulate aircraft installation.

NOTE: An investigation should be made to determine the magnitude of amplitudes, frequencies, and accelerations to which these units will be subjected. In cases where these values are higher than those specified herein, the higher values should be used.