



AEROSPACE INFORMATION REPORT

AIR4077™

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Mechanical Switch Usage for Landing Gear Applications

RATIONALE

AIR4077 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE:

This Aerospace Information Report (AIR) will examine considerations relative to the use of mechanical switches on aircraft landing gear, and present "lessons learned" during the period that these devices have been used.

2. PURPOSE:

The purpose of this AIR is to suggest specification, application, performance, and validation criteria for electromechanical switches used for environmentally severe applications on aircraft landing gear.

3. DISCUSSION:

Electromechanical switches have been used for position sensing needs on aircraft landing gear virtually since the advent of retractable gear. This AIR attempts to address some of the concerns of the designer who must apply and use these switches.

3.1 Characteristics, Performance, and Construction:

The switches used in modern-day aircraft applications are nearly all precision, snap-action switches. Construction details of these "basic" switches may vary; a typical example is shown in cutaway in Fig. 1.

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3.2 Definitions:

The following definitions are offered for clarification of terms used in this document. It should be understood that some switch manufacturers use slightly different terminology.

ACTUATION - Operating or releasing a switch by depressing or releasing its plunger or rotating its shaft.

ACTUATOR - The mechanical link that drives the plunger of a basic switch or the shaft of a rotary switch.

AUXILIARY ACTUATOR - A mechanism added to modify a switch operating characteristics, or to translate direction and/or amplitude of motion to direction and/or levels suitable for a particular switch.

DIFFERENTIAL TRAVEL - The distance from the operating point to the release point.

FULL OVERTRAVEL POINT - That position of the plunger beyond which further overtravel would cause damage to the switch or actuator.

OPERATING FORCE - The force that must be applied to the plunger to cause the moving contact to snap from the normal contact position to the operated contact position.

OPERATING POINT - The position of the plunger at which the contact snap from the normal contact position to the operated contact position.

OVERTRAVEL - The distance through which the plunger moves when traveling from the operating point to the full overtravel point.

PRETRAVEL - The distance through which the plunger moves when traveling from the free position to the operating point.

RELEASE FORCE - The level to which force on the plunger must be reduced to allow the contacts to snap from the operated contact position to the normal contact position.

RELEASE POINT - The position of the plunger at which the contacts snap from the operated contact position to the normal contact position.

RELEASE TRAVEL - The distance through which the plunger moves when traveling from the release point to the free position.

TOTAL TRAVEL - The distance from the plunger free position to the full overtravel point.

3.3 Existing Specifications:

- 3.3.1 MIL-S-8805: For the general type of switch under discussion, a switch configuration to fit most landing gear applications can be found within MIL-S-8805. The switches described by MIL-S-8805/39, /40, /43, /48 and /49 are readily available from multiple sources of supply. While there are similar products on other MIL-S-8805 specification sheets, they are usually single source products.
- 3.3.2 ANSI/EIA-5200000: For definition of switch tests, this document is a good reference. It is probably the most widely accepted industry standard relating to tests applicable to switches.

4. SPECIFICATION REQUIREMENTS:

4.1 Materials:

- 4.1.1 Standard parts, materials, or components that have a history of usage in similar applications are preferred for mechanical switches used in landing gear applications. This is not intended to preclude the use of new technology or improved materials, but only suggests that parts, materials, or components that have not been used in similar applications should be reviewed and tested carefully for adequate performance.
- 4.1.2 All exposed parts must be of corrosion-resistant material or protected to resist corrosion and structurally capable of surviving in the wheel well environment.
- 4.1.3 Switch design and construction should be such as to provide adequate moisture protection, as dictated by the landing gear environment.
- 4.1.4 Abutting dissimilar metals, as defined in MIL-STD-454 Requirement 16, should not be used when exposed to wheel well conditions without special precautions.
- 4.1.5 All potting or encapsulation compounds that are exposed to wheel well conditions must be hydrolytically stable. Suggested criteria are those of MIL-I-16923 for epoxies and MIL-S-23586 for silicones. Potting voids are unacceptable as they collect contaminants and moisture.
- 4.1.6 External components and surfaces should not be susceptible to or damaged by aircraft fuel, hydraulic fluids, cleaning agents, decontaminants, or landing surface debris such as dirt, sand, gravel, or grit from nonskid surfaces on ships' decks.
- 4.1.7 Switch selection must take into account expected temperature range of the environment.
- 4.1.8 Switches chosen should be compatible with the expected number of life cycle operations.
- 4.1.9 Part marking and other identification should be such that the permanence requirements of MIL-STD-130 are met.

4.2 Construction:

- 4.2.1 Electrical Connections: Switches may use integral pigtail wires, shielded cables, or connectors. If integral wires are used, care must be taken that these wires will meet the wheel well requirements, including vibration and wind whip (see AIR4004). Switches with integral connectors may be a viable alternative, and may increase maintainability, particularly where interconnecting wiring may be subject to frequent damage. If connectors are used, high-reliability parts such as MIL-C-38999 Series III or IV (hermetic seal types) are recommended.
- 4.2.2 Case Grounding: The exterior finish of the switch housing should permit grounding of the switch to its mounting structure in accordance with MIL-B-5087.
- 4.2.3 Sealing: The severe environmental conditions in the landing gear area demand that the switch be protected in a sealed enclosure. It is recommended that the minimum grade of seal for the switch be 1×10^{-6} standard atmosphere cubic centimeter per second; if possible, a true hermetic seal (1×10^{-8}) is highly desirable.

5. LESSONS LEARNED:

This section might alternatively be titled "Practices for Application and Use"; however, nearly all of the information covered has been gained in actual field experience, sometimes at the cost of considerable trial-and-error.

5.1 Mounting and Maintainability:

The switch mounting means should prevent all relative motion between the switch and the structure to which it is attached. In addition, care must be taken in relation to axis - the major axis of vibration or shock should not be the axis of switch actuator motion. Mounting and actuator structure must be substantial enough to provide reliable actuation during all expected conditions, and to clear or break ice that may be present in service.

- 5.1.1 Installations must be designed so that, under worst-case wear and tolerance extremes, the actuating mechanism always falls between the operating point and full overtravel point (for operated condition), and between the release point and the free position (for released condition).
- 5.1.2 Installation designs for switches should take into account not only the ease of initial installation and adjustment, but field maintainability requirements. In addition, the tolerances of both the switch and the installation must be clearly understood, so that the nominal design location of the switch is in the middle of the tolerance bands. This understanding of the tolerance buildups must also be translated to installation and adjustment instructions. One of the more common field problems has been that the switch mounting is adjusted until the switch just clicks, resulting in an installation that is almost never nominal in terms of ideal switch/mechanism position.

- 5.1.3 the goal of installation design should be to eliminate adjustment, or at worst to require adjustment only during initial aircraft installation. In other words, the adjustment, if any, should be only to the relationship between the switch mounting bracket and the actuating mechanism; once they are in the proper relative position, the switch should simply plug-in. This philosophy, if properly implemented in the installation design phase, allows any replacement of switches to be accomplished without special tools or rigging instructions.
- 5.1.4 All switch wiring in a wheel well must be tightly secured and the use of conduit for wire protection is recommended. Low point drains should be provided for all conduit or protective sheathing. (See AIR4004 for recommended wiring practices.)

5.2 Actuating Means:

Care must be taken that switch rated operating force is not exceeded by the actuating mechanism. A sometimes overlooked problem is actuating mechanism inertia - a high-mass, rapidly moving mechanism impacting a low-mass switch mechanism with resulting damage or shortened life of the switch.

- 5.2.1 The spring mechanism in an aircraft-quality switch is designed to hold the switch in the released position during all specified vibration/shock conditions, but not to serve as a return force for translational operating mechanisms external to the switch. Actuating mechanisms should have their own return mechanism and not rely on the switch spring return. This misuse of the switch spring, incidentally, is the most common cause of spring failure.
- 5.2.2 Roller plunger switches, when cam-actuated, should use cam designs as recommended by the switch manufacturer, with cam angles not exceeding 20 deg. If higher cam angles appear to be necessary to achieve the required accuracy of operating point, alternate design solutions should be sought.
- 5.2.3 For plunger-actuated switches, operating force must be applied along the actuating axis of the switch. Force applied at an oblique angle creates excessive side loading on the switch plunger, leading to early failure of the switch.

(For illustrations of guidelines on actuating means, see Figs. 5 through 7.)

5.3 Examples, Aircraft Installations:

Figs. 8 through 12 illustrate actual aircraft installations of mechanical switches, with notations regarding good or bad practices, or an analysis of probable switch failure modes.

Of all the problems reported, the two most common were:

- 5.3.1 Excessive Cam Angle/Side Loading: From the switch standpoint, these are essentially identical problems - striking the switch plunger or roller with a cam in excess of 20 deg, up to and including sharp edges (90 deg). The result of this is side loading on the switch - force perpendicular to the normal actuation axis of the switch. This results in either immediate damage, or excessive wear leading to eventual failure.

It is worthwhile to note that nearly all of these cases resulted from an effort to achieve high positional accuracy with the switch. In general, this is difficult to do when using a wiping or slide-by motion to actuate a switch, precisely because a gradual cam angle is required to translate the motion through 90 deg without developing excessive forces. Alternatives might include designing the installation to detect motion along the actuating axis of the switch; this, of course, would mean that the motion must stop before full overtravel point.

- 5.3.2 Insufficient Strength/Rigidity of Mounting: In an industry where weight is crucial, this type of error is understandable. Unfortunately, the laws of physics still operate - when a mass (a switch) is mounted at the end of a moment arm, and the entire mechanism is vibrated, the mass will move! The amount of allowable movement must be calculated, and the mounting bracket made rigid enough to limit the motion.

Calculation of loads must include ground handling. It is an unfortunate fact that, if a switch or its associated cabling are positioned so that they can provide a step or handhold they will at some point be used for those purposes.