AEROSPACE INFORMATION REPORT	**AIR5024™**	**REV. A**
	Issued 1999-04 Reaffirmed 2021-02 Revised 2022-07 Superseding AIR5024	

(R) Landing Gear Switch Selection Criteria

RATIONALE

This document revision update is to incorporate panel comments and current industry information and practices.

FOREWORD

This document is intended to provide the landing gear designer with switch and position sensing device information on appropriate technologies and means to achieve enhanced landing gear position sensing performance.

1. SCOPE

The scope of this document is to discuss the differences between electromechanical and proximity position sensing devices (sensor or switch) when used on landing gear. It also contains information which may be helpful when applying either type of technology after the selection has been made. The purpose is to help the designer make better choices when selecting a position-sensing device. Once that choice has been made, this document includes information to improve the reliability of new or current designs. It is not intended to replace recommendations from sensor manufacturers or actual experience, but to provide a set of general guidelines based on historic infromation of what is being used.

2. 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 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS1424 Fluid, Aircraft Deicing/Anti-Icing, SAE Type I

AMS1428 Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV

AMS1431 Solid Runway Deicing/Anti-Icing Product

AMS1435 Liquid Runway Deicinjg/Anti-Icing Product

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SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AIR5024A/

AIR1810 Design, Development, and Test Criteria - Solid State Proximity Switches/Systems for Landing Gear Applications

AIR4004 Guide for Installation of Electrical Wire and Cable on Aircraft Landing Gear

AIR4077 Mechanical Switch Usage for Landing Gear Applications

3. TECHNICAL DATA

3.1 Switch/Sensor and Target Description

A switch has two states, closed with electrical continuity allowing current to flow and open which blocks the current flow. A sensor has an output proportional to position.

Electromechanical switches consist of moving electrical contacts actuated by a mechanical connection to a monitored point such as a micro-switch or a magnet in close proximity such as in a magnet actuated reed switch. Electromechanical switches connect directly to electrical power and a load without any separate power needed.

Non-contacting proximity switches have been used on some aircraft as landing gear control and indication limit switches since 1965. There are two kinds of proximity sensing systems in common use: (1) proximity switches that have the switching electronics built into the sensing head and operate on the principle of eddy current losses or other proximity detection principles of a target material, and (2) proximity sensors that generally use variable reluctance and are connected to remote switching electronics contained in a separate electronics module. Proximity sensors produce an output that is a function of the distance between the sensor and its target, and this characteristic can be used to provide the maintenance technician with help during rigging. Proximity switches, on the other hand, provide a multistate output—“target near” or “target far.” Proximity detection implementation can be a simple coil of wire or a Hall effect integrated circuit.

Targets are used with proximity devices to assure consistent operation; it is not recommended to use landing gear metal directly as a target. Coil-based devices may use a metal target or a magnet target. Hall effect devices use a magnet target. Typical metal targets are a ferromagnetic material such as 4130, 4340 steel, or 17-4PH CRES. A highly conductive metal without perm such as aluminum, brass, or copper is called an “anti-target” and, when placed in between the proximity sensor and the target, will cause the proximity sensor to change state from target near to target far, which can be useful as a setup technique to force a system fault.

Example images of proximity switches and proximity sensors follow. Note that many of these devices look very similar, so one cannot tell what it is by how it appears.

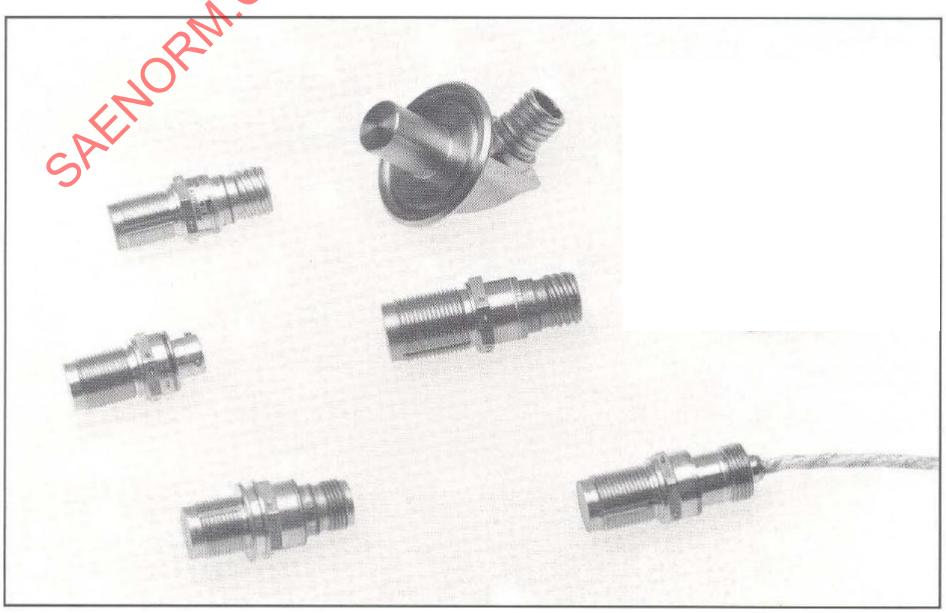

Figure 1 - Examples of one-piece proximity switches
Courtesy of Crane Aerospace and Electronics

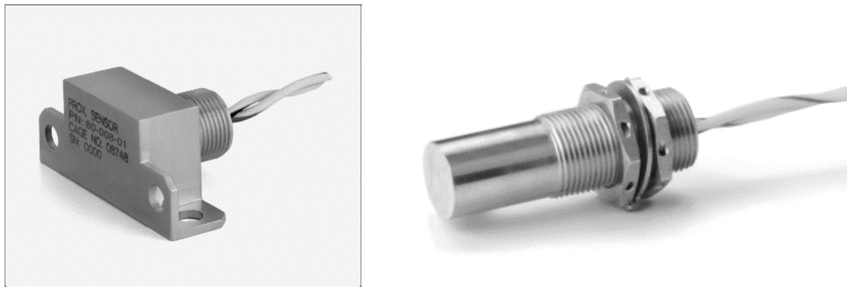

Figure 2 - Example proximity sensors
Courtesy of Crane Aerospace and Electronics

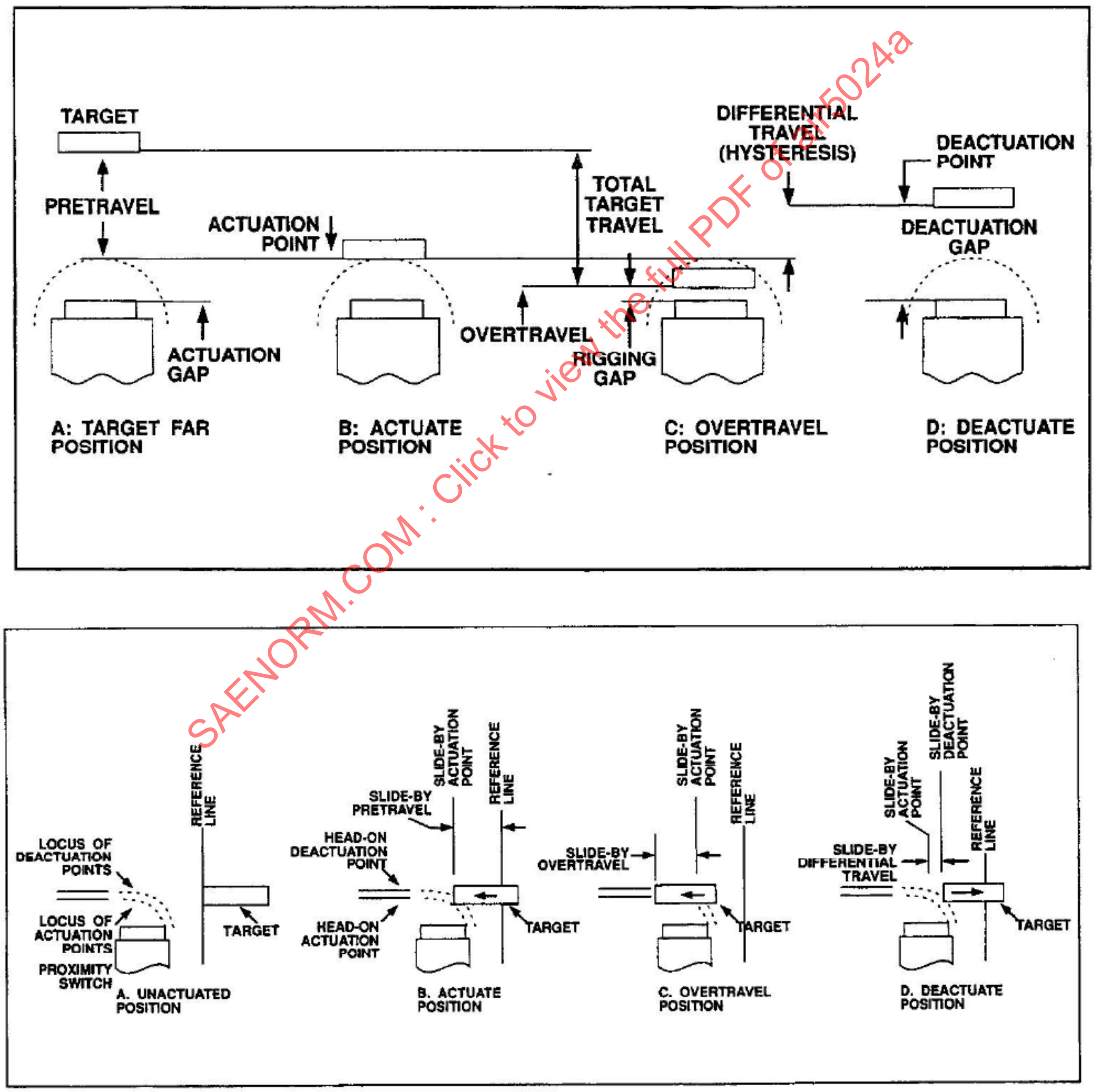

Figure 3 - Examples of target travel
Courtesy of and images copyright by Crane Aerospace and Electronics

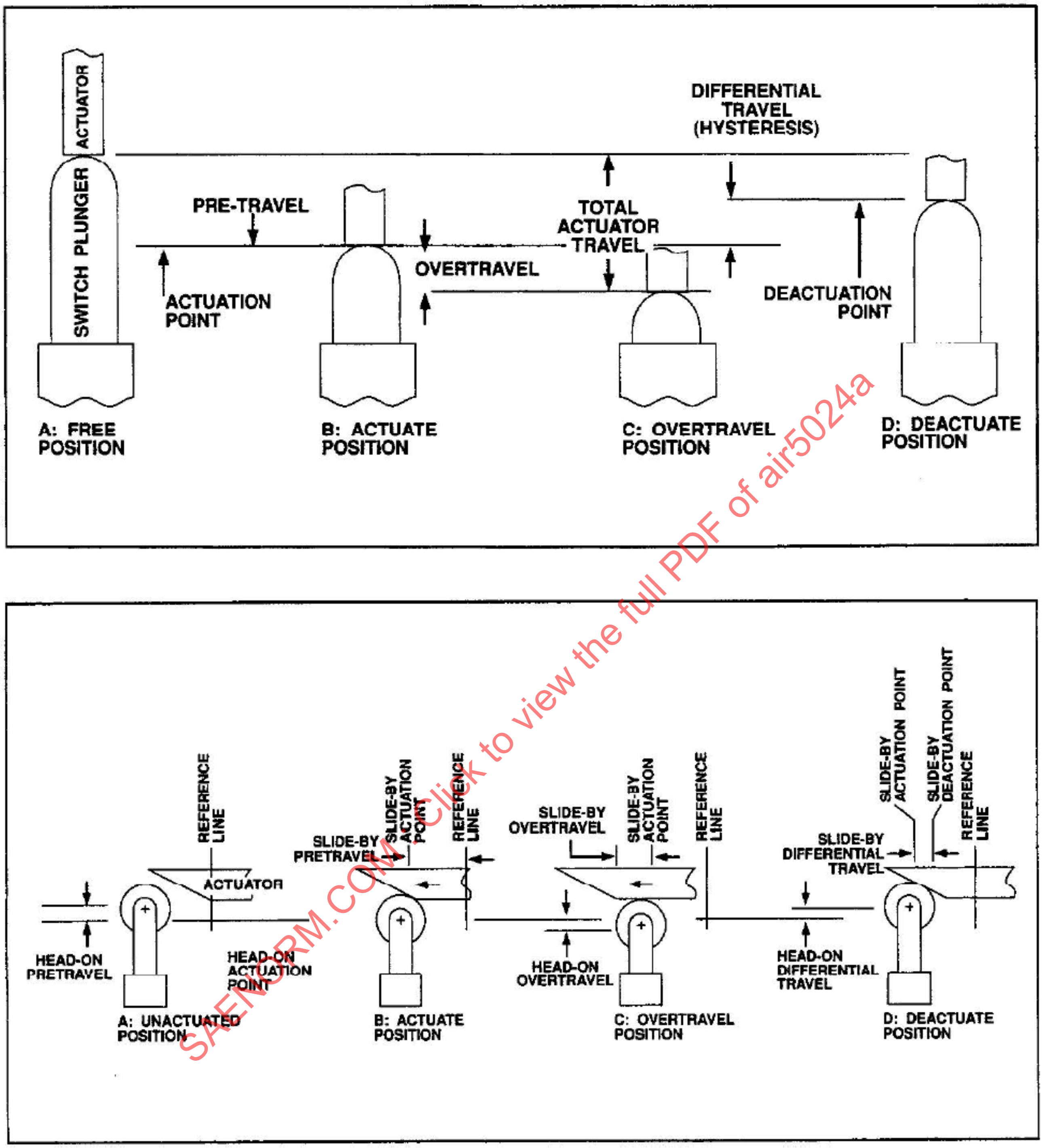

Figure 4 - Examples of mecanical switch actuation
Courtesy of and images copyright by Crane Aerospace and Electronics

3.2 Environmental Factors

a. Shock/vibration:

Electromechanical switches are affected by shock and/or vibration. Typically, the switch is most susceptible in the plane parallel to contact motion. In this plane, the switch contacts will tend to be separated causing the signal to be lost momentarily. Generally, switch contact separation longer than 10 µs may be considered a failure depending upon interface electronics or software. Once the shock and/or vibration has been lowered or removed, the contact will generally stabilize. The typical design values for sealed switches used on landing gears are up to 500 g sawtooth shock or 10 to 20 g vibration. Landing gear locking mechanisms can generate quite high g level shock that may damage a mechanical switch which could be addressed by damping the actuation.

Contact separation, especially repeated separations during high levels of vibration, will tend to prematurely wear out the contacts. Permanent damage to the electromechanical switch usually does not occur until shock and/or vibration levels are reached that are higher than required to separate the contacts. For each operation, the switch actually sees the contacts make and break the circuit on each separation caused by the shock and/or vibration. These separations can also cause false signals to be registered by electronic data processors without proper buffering or “de-bouncing.”

Proximity or Hall effect technology devices by design are less susceptible to the effects of shock and vibration since they have no moving parts. However, the reliability of the device can be reduced due to shock and vibration. Typical design values are 500 g shock and 30 g vibration for one-piece proximity sensors and 2000 g shock and 50 g vibration for two-piece sensors. Reliability and mean time between failure (MTBF) calculations reflect the environment in which the device operates.

It can also be noted that the target and mounting of the proximity sensor and the actuator and mounting of the electromechanical switch are designed be rigid enough to withstand the dynamic loads caused by the shock and/or vibration. Resonant frequencies of the sensor and brackets must be designed such that sensor assembly functions are not impaired. Vibration mode shapes are considered when selecting sensor mounting locations either on structural components or on the landing gear itself.

As a minimum, the vibration levels of DO-160 Table 8-1 applicable to landing gear (curves W of Fig 8-2 and P of Fig 8-5) are normally considered for test.

Acoustic noise induced vibration is normally considered, if applicable.

b. Radio frequency interference/electromagnetic interference (RFI/EMI):

1. Susceptibility:

Electromechanical switches are usually not considered susceptible to RFI/EMI. However, the wires connecting these switches to associated circuitry may require RFI/EMI shielding. One-piece proximity switches that include active electronics are susceptible to RFI/EMI, especially in severe environments, such as near high power radar or near/during lightning strikes. The RFI/EMI environment is carefully considered when designing the proximity sensor and its installation. Typically, there are specific RFI/EMI performance specifications that the proximity sensor is required to meet. Twisting lead wires, metal over braids, lead wire routing, ground connection location, as well as the device design, will minimize susceptibility. Meeting more stringent RFI/EMI threats typically requires filtering and protection circuitry which takes space and can greatly increase the size of a one-piece proximity switch. Powering the one-piece proximity switch from conditioned regulated power such as +15 VDC rather than raw +28 VDC aircraft power can minimize the size EMI impact.

2. Noise generation:

   Electromechanical switches can generate electrical noise depending on the load. Non-arcing loads below approximately 0.5 A generate lower noise. Arcing currents, especially those controlling highly inductive loads such as large solenoids or relays, can generate noise. Twisting lead wire, metal over braids, and lead wire routing can reduce or eliminate noise generation problems when dealing with arcing loads. Transient protection networks are usually provided on inductive devices. Coil type proximity devices generate a weak electromagnetic field to sense the target. This can be an interference problem if these proximity devices are mounted closer than 0.75 inch (19 mm) to each other for example in redundant detection installations. Communicate with the manufacturer for assistance in applying redundant proximity sensors.

c. Temperature:

Typically, electromechanical switches can withstand wide temperature ranges and rapid gradient shifts without damage or operating point shifts. Most aerospace switches operate at temperatures between -55 to 85 °C (-67 to +185 °F) with designs available from -55 to +125 °C, (-67 to +257 °F) or more. Higher temperatures than these require more exotic materials that increase cost and can limit life. It can be noted for electromechanical switches that use O-ring seals and elastomer boot seals tend to stiffen in extreme cold that can increase operating forces and reduce release forces or delay switch release.

Aircraft proximity sensors are currently designed for a performance operating range of up to -65 to 150 °C (-85 to +302 °F) for two-piece devices, and between -55 to 125 °C (-67 to +257 °F) for one-piece designs. Proximity switch operating and release points may shift during temperature excursions; shifts of up to 5% are possible. If shifts up to 5% can be tolerated, the operating temperature can be extended.

Reliability of the one-piece proximity sensor will typically be highest at room temperature due to the active electronics. Reductions in reliability and MTBF estimates can be made for devices which must see high temperatures or high thermal gradients, especially one-piece proximity devices with active electronics which will see this environment. Reliability and MTBF calculations for two-piece proximity sensors are largely unaffected by temperature extremes since their active electronics are generally located in the interior electronics bay of the aircraft. Current two-piece sensor designs are all metal sealed units, intended to last the life of a 40000 cycle aircraft.

d. Sealing:

Electromechanical switches range in sealing from completely open to true hermetic sealing. Hermetic sealing is defined as metal to metal or glass to metal seals with a helium leak rate of less than 2.7 x 10^{-6} atm-cc/s at standard temperature and pressure conditions for proximity sensor or switch typical device sealed volumes. Resilient sealing is the most common seal in the aerospace industry. These switches have O-ring seals at the plunger with glass to metal seal around the basic switch. The factors to determine seal level in an electromechanical switch are as follows:

1. Use a sealed switch when the switch will be exposed to a dirty environment in storage, assembly, or operations.

2. Use a higher level of sealing when the contacts will not have an arcing load. Switches that have arcing loads tend to self-clean the contacts. Low energy loads tend to be more susceptible to contamination.

3. Use a higher level of sealing when it is an extremely important function or the switch may not be used for long periods.

The seals, including the O-ring material, as well as any potting material, are selected to be compatible with fluids in the intended environment.

Current proximity switch and sensor designs have an all-metal case with an elastomer compression lead wire seal, or a hermetic connector. Sealing baseline is at 1 x 10^{-5} atm-cc/s, with 1 x 10^{-8} atm-cc/s available if using a connector. Passive (simple coil) proximity sensors and hermetic proximity switches are considered explosion proof by design. Potting materials are not currently used. Older proximity sensor designs with plastic faces meet the 1 x 10^{-5} atm-cc/s criteria unless damaged by hard physical contact.

Note that “atm-cc/s” refers to a gas leak rate of cubic centimeters per second measured at atmospheric pressure.

e. Ice:

Ice buildup on the plunger or actuator of electromechanical devices can reduce the switch's ability to release. Rarely is this a problem and typically only on installations where the switch is directly in the airstream. Testing in the laboratory for ice buildup is difficult and does not yield practical results. Release forces of 4 lbf (17.8 N) minimum for plunger switches subject to icing conditions are considered sufficient.

Likewise, ice buildup on proximity devices is rarely a problem. Slide by installations in lieu of direct approach installations are preferred to reduce potential for malfunction due to the buildup of ice or foreign object damage (FOD).

3.3 System Requirements

a. Contact arrangements:

Most aircraft electromechanical switches have multiple throws and poles and can be easily wired redundantly. Single pole, single throw is usually necessary if hermitic sealing is required. Generally, electromechanical switches drive banks of relays within the aircraft and switched power levels are of concern in fuel areas, particularly in fault conditions.

Proximity switches are usually single pole, single throw. Proximity sensors and switches in simple form have a single on-off output that can be configured into multiple outputs or logic equations through their mating electronics. This system is also "checkable" by using built-in test (BIT) logic

Hall effect type solid state switches require a magnet target for actuation of a hall sensor inside the switch. Outputs may be on-off or proportional to magnetic field strength. Hall type switches are compatible with low supply voltages of 5 VDC or even lower.

Solid state switches can be two or three wire configuration. Two wire type are operated in a current loop with switch state corresponding to different current levels. Three wire type have supply voltage, ground and output connections with switch state corresponding to voltage level. Multiple output states are possible to indicate certain switch conditions such as target near, target far, indeterminate (output between near or far), open wiring, or shorted wiring.

b. Load capacity:

Electromechanical switches can handle extremely low voltages and currents up to high power loads. Typically, aerospace switches have silver or silver base contacts and are designed to handle from 0.5 to 5.0 A or more. The number of operations required determines the maximum current the switch can handle. Electrical life of most aerospace switches is 25000 operations. In most cases, reducing the current will increase the number of operations the switch will make or increase the switch's reliability. Note that this applies to arcing loads only. Reducing the load below arcing levels changes the failure mode. Clean silver contacts have no minimum current or voltage requirement. However, switch manufacturers will usually specify gold or other precious metals below arcing levels. This is because gold and some other precious metals are softer and less likely to develop films which can cause non-contact. The contact can be configured in several manners to increase reliability at non-arcing loads. Examples of the configurations are serrated, pimple, bifurcated contacts, and wiring multiple basics redundantly. At non-arcing loads, the level of sealing becomes even more critical since failure to make the circuit because of contact contamination is the most likely failure mode.

Proximity switches can be designed to switch any specified load. Common specified loads are 0.5 A or less.

c. Actuation accuracy:

Aerospace electromechanical switches are very repeatable on operating and release points. The mechanical wear of the switch plunger or actuator and the electrical wear associated with arcing loads can cause some shifting. If the plunger and actuator surfaces are required to slide together, a friction reducing scheme is suggested to be used. Most switches can be obtained with roller plungers or ball bearing plungers. Using lubrication will increase the likelihood of contaminating the switch.

Although electromechanical switches have very precise operating and release points, beware teasing by just slightly operating or just slightly releasing it. A switch that is very close to its operating or release points is more susceptible to shock and vibration, erratic contact, and contact welding due to reduced contact forces. If the travel is very limited or the switch must operate very slowly, contact the switch supplier for suggestions.

Proximity devices vary more widely in operating and release points. Temperature variations, changes in surrounding metal, target material, and even target material hardness can have effects on the actuation point of the proximity device. Proximity devices typically vary the switch point less than 5% from low to high temperature extremes. The way the target is designed can have a strong effect on operating repeatability. Slide-by-targets with sharp corners give the most accurate results. Although the initial switch point may vary slightly from predicted values due to surrounding metal, once installed and rigged to the target, switch points do not vary over time and are not susceptible to wear. An aircraft structural component is not suggested as a suitable proximity device target because target characteristics are not as tightly controlled thus the GA and GD curves may not apply. Check with the particular proximity device manufacturer if using a target other than that provided by the manufacturer for that device.

Generally speaking, replacement sensors may be changed out of aircraft installations with no further rigging required.

d. Self-test requirement:

Electromechanical switches are usually not designed with self-test features. However, a resistor can be wired across terminals to determine if the open contact is wired correctly. Many times, this can be designed into most existing packages for a slight additional cost.

Proximity or Hall type solid state devices can be easily designed with self-test features. The more complex the testing requirements, the more circuitry, size, and cost is required. Two-piece devices with remote electronics also have numerous other logic, matrix, and software function capabilities available and rigging gap readouts are now common.

e. System weight:

It is difficult to compare the two types since numerous factors are involved. Actual switch components may be very similar but other considerations, such as lead wire gauge, or the need or addition of a relay may determine the final system or function weight. Because of the relative low weight of either device, the weight differential is usually not very significant.

f. Envelope requirements:

Again, it is difficult to compare. Designers can use standard package sizes if they have standard requirements. For best results, consult the sensor manufacturer for envelope size requirements before the final design is done. Size of the envelope can be a determining factor on switch selection.

g. Cost:

The costs are usually lower for electromechanical switches compared to proximity sensors. Electromechanical prices may increase significantly for improved sealing and temperature capabilities needed for landing gear environments as well as for unique designs.

Proximity device costs are increased with self-testing functions and longer sensing ranges. Cost can be driven by use of high reliability electrical components.

It may be desirable to evaluate overall costs spread over the life of the aircraft. Higher acquisition costs may be recovered over the life of the aircraft when the switch/sensor device is designed to operate in a harsh environment.

h. Reliability/life:

For electromechanical switches, life is usually defined as a number of operations at a certain load and environmental conditions such as dirt, wear, corrosion, vibration and shock. The life of the switch is determined as much by the switch as the uniqueness of the load it is handling. Electromechanical switches tend to have a shorter but more predictable life.

For proximity switches, life is typically measured in hours or MTBF and MTBF is usually above 400000 hours. These estimations are best made with actual data or corrections for environmental effects mentioned earlier, such as temperature extremes, high temperature gradients, or shock and vibration. A proximity switch's life is usually longer, but less predictable.

The prediction for MTBF for a new application is typically based on prior service history and the application being developed. The reliability of either device can be greatly enhanced by correct application of design and installation.

Reliability can also consider installation effects, any targets, or other system aspects such as redundancy.

i. Commonality:

Consider system commonality factors when specifying switches such as ways to use the same part number in multiple applications by checking with the airframer or system integrator to determine if an existing specified switch can be applied in other locations or systems. Ask suppliers if they already provide a similar switch for this aircraft or have an off-the-shelf switch that may work with reasonable changes to the installation. Check if a two-piece proximity sensor system is on the aircraft and if an extra electronics channel is available or more channels can be added for the application.

3.4 Installation Considerations

Installation generalities are addressed in some detail in both AIR1810 (for proximity switches) and AIR4077 (for electromechanical switches).

a. Rigidity of mounting:

In general, this is important for any sensing technology. A device used for position sensing is, in another sense, a motion detector. If the mounting is not rigid enough to control or eliminate unplanned motion under all conditions of shock, vibration and ground handling loads, the sensing device will see the motion. Due to their non-contact design and built-in hysteresis band, proximity sensors are not susceptible to wear caused by unplanned dynamic motion in the sensor mounting bracketry during any transitional condition of actuation to non-actuation. Switch installations must have sufficient structural soundness to withstand any loads which might be applied during normal ground maintenance on the air vehicle (mechanics standing on brackets or using bracket mounts as hand holds, etc.). A minimum manhandling load of 250 lbf (1112 N) is suggested

b. Cam angle:

Electromechanical switches are generally specified to operate with cam angles of less than 20 degrees. Excessive cam angles cause excessive wear and result in early failures, but low cam angles add variation to the switch point.

Proximity switches, because no mechanical contact is required, do not have a critical cam angle. In fact, for easy rigging measurements, a sharp leading edge (90 degrees) on the actuating surface is ideal.

c. Actuation force:

Electromechanical switches require an actuation force, typically 6 lbf (26.7 N) actuation and 4 lbf (17.8 N) release. That force is a function of the internal springs. The springs are chosen to control the required actuation force, provide adequate return force in icing conditions, and protect against some level of vibration and shock. Normally, switches are not to be used as a return force for an external actuating mechanism. These actuation forces can lead to wear due to repeated contacts.

Proximity switches require no actuation force. In fact, because they are designed as a “no touch” device, installation design best practice is to guard against physical contact between the target and the face of the proximity switch. Some of the more recent all-metal sensor designs specify a maximum number of inch-pound impacts to the sensing face that can be tolerated. On these sensors, non-contact is still generally recommended to avoid a possible wear source.

d. Wet installations:

For wet installations, such as monitoring landing gear strut internal metal, take careful note of pressures involved including any test overpressures that may be applied when the switch is installed. All seals are selected to be compatible with the working fluid including over full temperature ranges. Consideration of the use of a well to isolate the switch from the fluid and pressure is normal. Take into account the effect of the well on the actuation and de-actuation points.