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## Switch Ratings, What's it all Mean?

Just catching up on piles of snail-mail and e-mail that tends to build up while we are flitting from fly-in to seminar. Picked up a copy of the Oct 97 issue of Van's Air Force and read an article on switch selection that makes some good points but arrives at the wrong conclusion. The author was privileged to observe some work done at UL Laboratories on switches and expressed some concern for builder naivety with respect to AC versus DC ratings.

He correctly cites an increased difficulty for breaking a DC circuit versus an AC circuit . . . particularly when inductive loads are involved. Quoting from the article:

*"Typical of this is the roller and bar micro switches made by MICRO(switch) Corporation. Rated at 10 amps for 125/250 volt AC, the same switch can only carry 0.15 amps at 250 volts DC! The voltage stayed the same!"*

The statement is true but not relevant to our task. We're not building 250-volt airplanes, we build 14 and a few 28-volt airplanes. Check out this data table plagiarized from the same Microswitch catalog . As one picks from the various switch products in the catalog, an "electrical code rating" is quoted for each device . . . the chart above states the ratings for each code. When one buys a toggle switch from Microswitch . . . the choices above are all inclusive.

The chart cites a variety of conditions for applying switches. Various combinations of AC or DC voltage along with loads can have a profound effect on switch life. Inductive loads do call for some derating . . about 25%. However, look at the column for lamp loads . . . it calls for the greatest derating . . . on the order of 75%!

I'll call your attention to the 250 VDC column for ALL switches. Note that none are rated at more than 0.5 amps in spite of the fact that the same switches are good for 6 amps at 250 VAC and MANY more amps at lower voltages.

Quoting again from the article:

*"Those of you who can still remember the old Kettering coil ignition systems will recall that when the condenser in the distributor went bad, the points generally turned blue and melted down in a few minutes. . . ."*

The cited capacitor was to slow down a the rate-of-rise for voltage across relatively slow moving, cam driven switch contacts. If an arc were allowed to form between the opening points, energy intended to spark combustible mixtures in a cylinder would be used up at the points instead . . . the most notable result of bad "condenser" was the car ran very badly if at all . . . the points were indeed subject to more electrical stress but seldom for very long . . . this situation demanded timely repairs. Switches of choice for airplane panels are not cam driven. Toggles use spring loaded, over-center mechanisms that provide higher contact spreading velocities. Going on with the article . . .

*"Cockpit switches don't have benefit of the condensers to absorb the electrical inertia present in a DC circuit and as a result, the gap temperatures get hot enough to weld contacts. That includes AC rated switches, even those made with exotic high temperature alloys."*

The Kettering ignition example is an excellent way to illustrate "inductive" circuits. However, there are few such circuits in an airplane. Most notable of these are battery and starter contactor coils. We don't put "condensers" on these systems but we do install "catch diodes" or MOVs (metal oxide varistor) to protect switch contacts. This has been standard practice in airplanes for 30+ years (just worked on my kid's '72 Chevy truck today and saw a 1N4001 diode crimped into the connector for the air-conditioning compressor clutch). The article also overlooks the differences in physics between burning contacts and welding them.

Toggle Switch Ratings Table from Microswitch Catalog									
Elect Code Rating	28 VDC			115 VDC	250 VDC	115 VAC			230 VAC
	IND	RES	LAMP	RES	RES	IND	RES	LAMP	RES
1	15	20	5	.75	.5	10	15	3	6
2	10	15	4	.75	.5	7	15	2	6
3	15	20	7	.75	.5	15	15	4	6
4	10	18	5	.75	.5	8	11	2	6
5	12	20	5	.75	.5	15	15	4	6
6	10	18	4	.75	.5	8	11	2	6

Most damage to switches is done during the breaking of a circuit where an arc forms in the widening gap. Depending on contact spreading velocity -AND- thermal mass of the contacts, this can be the most stressful task for switching. However, this is when the contacts are getting farther apart . . . an improbable scenario for welding.

The physics for closing a circuit are different. Here, potentially high inrush currents are impressed across contacts that may have small hills and valleys eroded in them from previous switch openings. These little hills become potential welding material when the large inrush current is forced to flow through a small cross section of material. This can happen to any switch with either DC or AC.

By-in-large, switched circuits in airplanes are resistive but let's look again at the purloined data from Microswitch. In nearly all cases (except Code 5) DC ratings at 28 VDC for the switches cited are better than the ratings for 115 VAC! (????) As a general rule of thumb, I've told builders that the 115 VAC rating is directly translatable to 14 VDC applications. I'll offer the chart above in support of this advice. The article continues . . .

*"What often happened during UL testing was that the points welded shut, making it impossible to open the circuit."*

Sure, let me pick the test parameters and I can probably weld about any switch shut. Keep in mind that UL has to test for EVERY possible safety contingency in product design and utilization. We design and build failure tolerant designs

and select electrical devices that perform in narrowly defined settings. In years of fiddling with airplanes, I've never seen a manual switch weld shut. I've seen them corrode open, I've seen over-center springs rust out, I've seen wires break off the back, etc. But never a welding. Now, contactors weld . . . with some frequency . . . but that's another topic. Electrical stresses that weld switch contacts in the lab simply don't exist in airplanes. Most switch failures I've observed show up when the switch fails to make good contact . . . mostly from dis-use and corrosion as opposed to electrical abuse.

The heaviest currents handled by panel switches are landing/taxi lights (which have their own special inrush values -see "lamp" ratings in table above), and pitot heat. For most 14-volt airplanes this is about 8 amps. Everything else drops rapidly from there. I can also tell you that switching an 8-amp landing light with a 4-amp "lamp" rated switch is not an automatic formula for welding. The 200% "overload" will indeed reduce the life of the switch. However, let us suppose the switch was originally rated for 10,000 cycles (a low estimate) and the reduction was to 10% of rated life(also very low) . . . How long will it take you to put 1000 cycles on your landing light switch? Further, while one applies MOV or catch diodes for controlling inductive circuits, inrush limiters in high-current lamp circuits may be used to insure that stresses on the switch are only slightly more than purely resistive loading.

In a nutshell, 125 VAC ratings equate favorably and conservatively to 14 VDC ratings - as long as the switch has a healthy "snap" action . . . all toggle switches and most

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rocker switches do. Just because the numbers stamped on the side of the switch don't mention a DC capability doesn't mean that the switch doesn't have one. Manufacturers are unable to put ALL of the information from the chart onto the side of every product, the lettering would be too small to read!

The article also alluded to a 3X increase in the price of switches to get "DC rated" devices and postulated that delta-dollars for 10 switches would be \$35. Hmmmmmm . . . this means that the original switches being compared cost

about \$1.75 each! I can't think of any \$1.75 switch I would consider for use on an airplane and it has nothing to do with AC/DC ratings! The switches we stock sell for \$5.00 in a single-pole device and carry no markings for DC ratings. They are rated at 7 amps or better at 115 AC and will work just fine in virtually every slot on an airplane panel. No matter where you choose to purchase switches, know that concerns raised by the original article are unsupported either by experience or failure mode physics.

Happy switching.

THINGS YOU CAN DO WITH SWITCHES

Say what? Everybody knows that switches turn things on and off. What's the big deal? I'd agree that most of the switches we operate every day are simply a handy means of opening and closing a gap in a wire. I'll add that switches come in a variety of flavors. Aside from the simple on/off control of, say a light bulb, variations on a theme give us handy tools to simplify a variety of switching tasks.

Table 11-1. AeroElectric Connection S700-Series Toggle Switches			
Dash No.	# of Poles	# of Positions	Action Keyway - Center- Opposite
1-1	1	3	ON-OFF-ON
1-2	1	2	OFF-none-ON
1-3	1	2	ON-none-ON
1-5	1	3	(ON)-OFF-ON
1-7	1	3	(ON)-OFF-(ON)
1-8	1	2	(ON)-none-ON
2-1	2	3	ON-OFF-ON
2-2	2	2	OFF-none-ON
2-3	2	2	ON-none-ON
2-5	2	3	(ON)-OFF-ON
2-7	2	3	(ON)-OFF-(ON)
2-8	2	2	(ON)-none-ON
2-10	2	3	ON-ON-ON
2-50	2	3	(ON)-ON-ON
2-70	2	3	(ON)-ON-(ON)

First, I'd like to introduce you to our numbering convention. As we update schematics and power distribution diagrams, we'll try to add more detail to a switch's description. Adjacent to the reference designator number (S1, S2, S3, etc.) we'll include in parentheses the dash number out of Table 11-1 which describes the switch's number of poles, number of positions and its action.

The left column of Table 11-1 is the suffix to add to the basic switch specification number. To fully describe a switch you

would precede it with the standards number followed by the dash number appropriate to the action you want. For example, an S700-2-7 switch is a two pole, three position toggle switch spring loaded to center from both extremes and having an (ON)-OFF-(ON) action. The parentheses ( ) around an action label means the switch is spring loaded to leave that position when released. Other styles of switches (like rockers) will replace the "S700" with another number but the dash number to describe the number of poles: number of positions and action will remain the same.

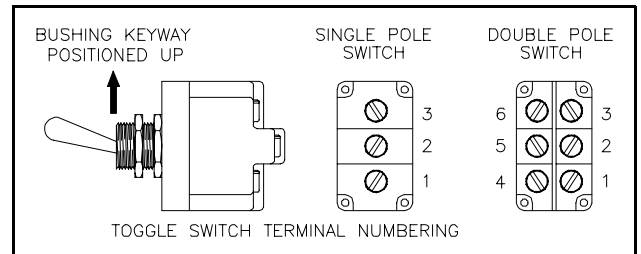


Figure 11-11. Toggle Switch Terminal Numbering.

We'll standardize all our drawings to conform to the above terminal numbering convention for switches. The mounting for a toggle switch is a 15/32" threaded bushing with a keyway cut on one side. Switch actions described in the last column have keyway side positioning of the toggle first, followed by center positioning (3-position switches only) and opposite side positioning on the right. For most applications, switches are mounted with bushing keyway oriented UP in the panel.

It is appropriate to mention here that toggle switches can be difficult to keep tightly mounted in the panel. This is because it's attached with threaded fasteners and you're always yanking on its handle. You could use thread-locker to make the nuts difficult to move after the switch is installed but this makes the switch difficult to replace later.

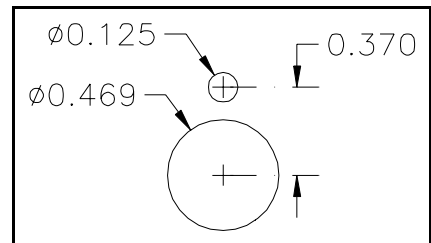


Figure 11-12. Hole Layout for S700 Series Toggle Switches.

The best solution is to take advantage of the anti-rotation keyway washer and internal tooth lockwasher that is supplied with all switches from our catalog. The keyway washer has two tabs, one to engage the keyway in the switch bushing, the other to engage a 0.125" hole that you need to drill in the

panel, 0.37" above the 15/32" mounting hole. The anti-rotation keyway washer installs from the back and will not protrude through a panel of .062" thickness or more. Most panels have a placard to label the switches that will cover a 0.125" hole. Inclusion of this hardware in your installation will keep the switches right where you installed them. Leaving thread-lockers out of the installation will make them easy to replace should it become necessary.

By the way, you'll find a 9/16" "Spin-Tite" or nut driver very useful when installing or replacing toggle switches. I have several that have been polished with crocus cloth to a very shiny surface where it touches the panel. This little modification to the stock tool assures you that it cannot scratch your panel placard . . . even if it's plastic.

### SINGLE POLE SWITCHES

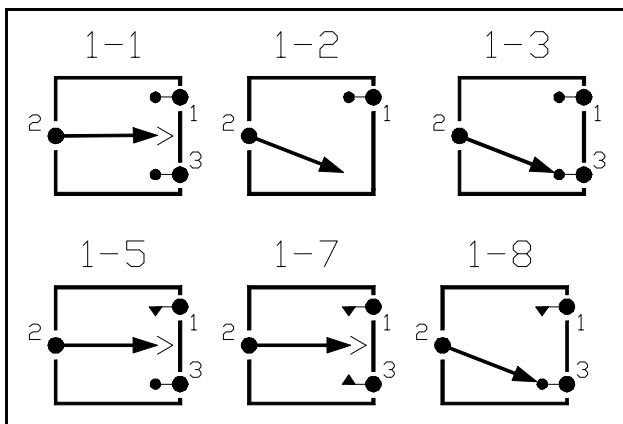


Figure 11-13. Family of Single Pole Switches.

Here's how the single-pole switches look in our schematics. The symbols have a great deal in common but there are differences that give you clues as to what kind of switch is being called out . . . and how it works.

First, I'd like to point out the ">" symbol between terminals 1 and 3 of three switches illustrated in Figure 11-13. This tells you that there is a center position that makes it a 3-position device. Switches without this symbol are 2-position devices. Note also that the moveable "arm" of the switch can be swung to make contact with either a solid dot (●) or a solid triangle (▼). The dot represents a sustained position for the switch while the triangle represents a momentary or spring loaded position.

Okay, 6 kinds of toggle switches . . . why would we want so many and what would we do with them?

**1 dash 1, ON-OFF-ON** switches are useful for selecting either of two devices with a both off position. How about

having a landing and taxi light fixture share a single fuse or breaker? Terminal 2 connects to the bus, terminal 1 might power the landing light fixture while terminal 3 connects to the taxi light.

**1 dash 2, OFF-none-ON** switches are useful for any simple task of controlling nav lights, landing light, fuel pump, pitot heat, etc. We don't stock this kind of switch because a 1-3 switch has the same functionality. If you want a **1 dash 2**, we can supply it to you. Note that the only "ON" condition is with the toggle placed opposite the keyway. To use this style switch for a landing light, you would have to mount it keyway down in order to have the switch close when the toggle is moved up. On the other hand, a **1 dash 2** switch would serve nicely as a magneto switch. Unlike landing lights, magnetos are "ON" when the switch is open. I've included them in the family tree of switches because they do exist.

**1 dash 3, On-none-ON** switches select either of two circuits but doesn't permit both to be off. Obviously, terminal 3 of the **1 dash 3** switch can be ignored when the switch takes on simple tasks of the **1 dash 2** style switch described above. Since connection is made at both extremes, you could use a **1 dash 3** switch to use a single fuel gage to monitor either right or left-hand fuel tanks. Or how about switching a single dimmer between to lighting loads, say a map light and an overhead flood?

**1 dash 5, (ON)-OFF-ON** switch has one position spring loaded to center, the other is a sustained position. One application that comes to mind would be an ignition-start combination switch for an engine like a Rotax. Terminal 2 would be connected to ground. Terminal 3 would ground the ignition in the down position (kill the engine), leave the ignition free to function in the mid position, and operate a ground-to-energize starter contactor in the up position. Here's a first example of getting a single switch to do two separate but related functions. I've had some builders use the **1 dash 5** switch for electric flaps where a single action selects fully "extended" flaps but the spring loaded "retract" operation is conducive to milking the flaps up during a go-around.

**1 dash 7, (ON)-OFF-(ON)** switches have momentary throws both sides of center. This action might be used for electric trim operations where momentary blips to either direction of trim are desired. On of my Defiant builders plans to use a **1 dash 7** switch to control front and rear starter contactors from a single switch.

**1 dash 8, (ON)-none-OFF** switches have a sustained and momentary contact at either extreme of two positions. The **1 dash 8** action could be used to replace a push-button where

terminals 2 and 1 are used to momentarily operate some device (like the starter contactor).

TWO POLE SWITCHES

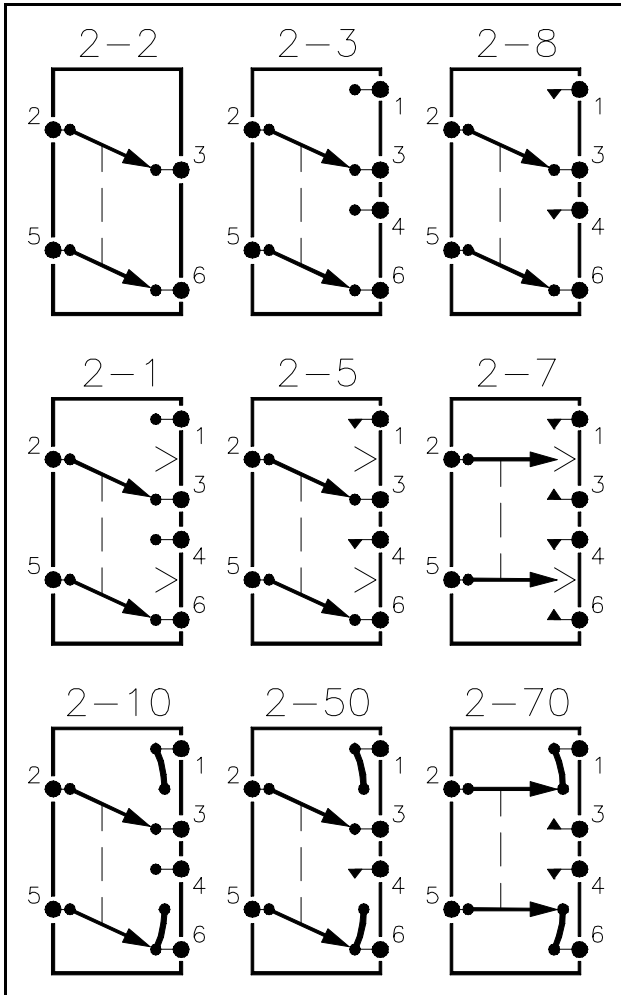


Figure 11-14. Family of 2-Pole Switches.

Wow! wouldja look at all those two-pole devices! You'll recognize the first 6 as close cousins to the single pole devices shown earlier. We've simply doubled up the mechanism so that two switches side by side share the same behavior. When a 3-position switch has more than one pole, small changes in the transfer mechanisms can yield some unique functions.

I don't have applications for all of the switching actions depicted but here are a few that I've used in the past. Some of these are also shown on our power distribution diagrams and wire-book examples.

**2 dash 3, On-none-ON** is a common part number we stock. This device is recommended for combination battery-master/alternator-field switching. MUCH less expensive than the popular but unnecessary "split rocker" found on many certified ships, the **1 dash 3** works quite nicely in this position. The **1 dash 3** also serves nicely as a magneto switch. You can use terminals 2 and 3 to kill the magneto in the down or OFF position. The other pole is used in series with the second magneto switch. Properly wired, you can disable the starter except when the impulse coupled magneto is ON and the non-impulse coupled magneto is OFF. Use of toggle switches with a starter lockout feature eliminates the kickback hazard inherent with the key-type OFF-L-R-BOTH-START switches found on most certified single engine ships. Furthermore, toggles are easier to mount and much less expensive than the key-switch. The big bonus of using toggles comes when and if you replace either or both magnetos with electronic ignition. The existing toggle is "electronic ignition ready."

**2 dash 7, (ON)-OFF-(ON)** is commonly found in trim or flap systems that use permanent magnet motors. When wired as shown below, the **2 dash 7** reverses polarity of power applied to the motor to reverse its direction.

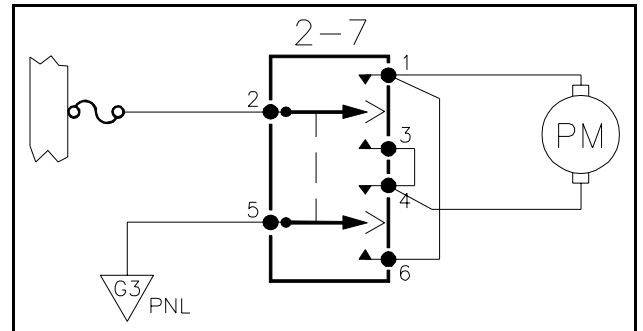


Figure 11-15. example of a 2 dash 7 Switch Application.

The spring loading to center from both extremes makes it easy to "bump" the switch for small trim changes.

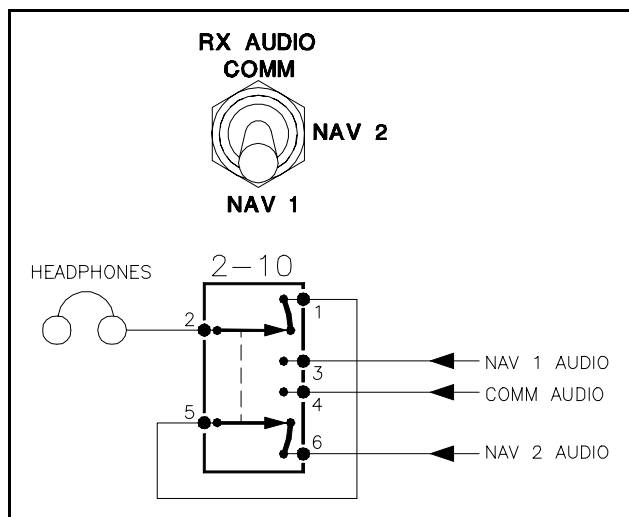


Figure 11-16. Example of a 2 dash 10 Switch Application.

**2 dash 10, ON-ON-ON.** Here's an interesting example of how you can wire a 2 dash 10 switch to implement a single-pole, three-position action. In the drawing above, I show how a headset can be switched individually to any of three audio sources. Incidentally, four pole switches are available in the dash 10 configuration so that you can implement a 2-pole, three-position configuration.

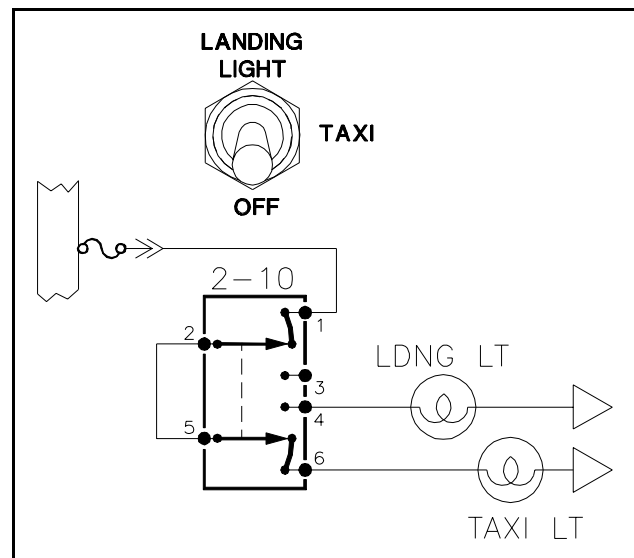


Figure 11-17. Example of a 2 dash 10 Switch Application.

Shuffle the wires a little bit on a 2 dash 10 and you can control landing and taxi lights from a single switch powered from single source.

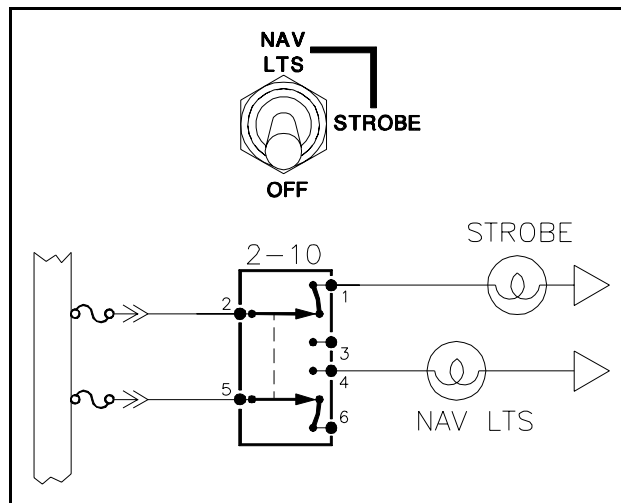


Figure 11-18. Example of a 2 dash 10 Switch Application.

Another space saver for switch panels uses a 2 dash 10 switch to control both strobe and nav lights. The first position brings up the strobe lights while the second adds nav lights. Each lighting circuit has its own power supply and circuit protection.

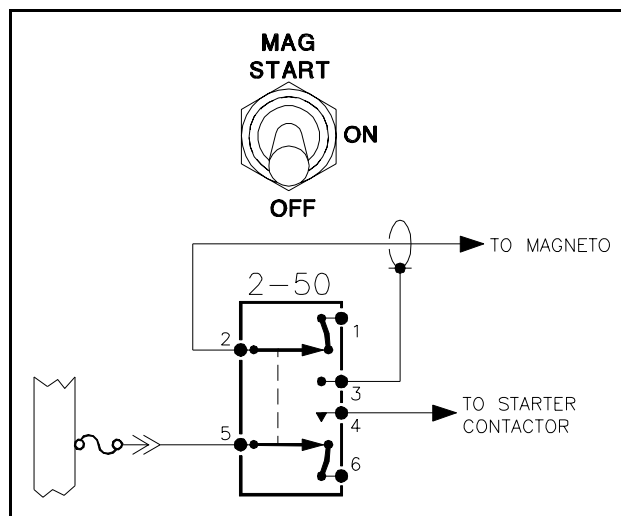


Figure 11-19. Example of a 2 dash 50 Switch Application.

Here's a way to combine magneto switching with starter control. Using the 2 dash 50 in this configuration makes it easy to change out magnetos for electronic ignition at a later date. Just use terminals 1 and 2 to control DC power to the ignition system.

4-pole versions of these switches follow the same numbering conventions. The need for a 4-pole device is pretty rare but a **4 dash 10** switch could be wired as a 2-pole, 3-position transmitter select switch or perhaps to use a single instrument for monitoring volts, main alternator load and aux alternator load.

Virtually all applications I've had for 4-pole switches were some small signal application where a miniature toggle was called for. We may not stock these soon but if you need one and have trouble procuring it, we'll be pleased to assist.



## **Resistive Load**

Resistive loads can be purely resistive or of the tungsten-heater load type. A resistive load that has no heating element is the easiest for a switch to handle, and the switch's rating is based on this type of load. A resistive load is one in which 100% of the load is composed of resistive devices. Current through the contacts is constant throughout the make, carry and breaking actions for the switch. Contact erosion is very low for switching purely resistive loads .

## **Lamp Load**

When a switch closes on a lamp load, the switch sees a short duration inrush current because the cold resistance of the lamp filament is very low. The surge current as the switch closes can be many times the steady state current. As the lamp filament heats up to operating temperature, the resistance of the filament increases and the current decreases to the lamp's rated steady state.

## Motor

Motor loads present yet another brutal environment for switch contacts. Closing the switch contact on a motor start-up load causes very large current surges of about 3 to 8 times the running current.

## Inductive Load

As a switch on an inductive load is opened, the inductor, or transformer, induces a counter option "voltage" in the circuit. This voltage opposes any change in the circuit current and can reach hundreds of volts. This extremely high voltage can restrike the arc as the switch contacts open resulting in severely eroded or welded contacts.

## Capacitive

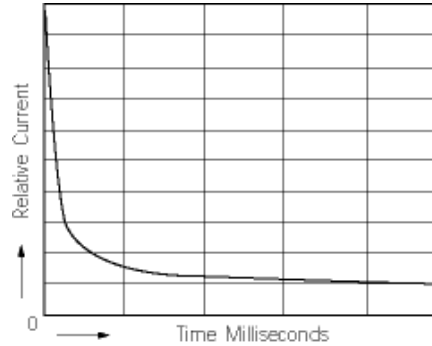
With such loads as DC power supplies, welding machines, and strobe charging units the inrush current is even more damaging than with inductive loads. To the switch a capacitive load appears as a dead short as the switch closes. In the first few milliseconds the inrush current can sometimes reach 100 times the steadystate current of the circuit. Even worse for the switch, this inrush occurs before the contact bounce has subsided. This produces severe arcing and contact erosion. The contacts may stick or weld upon closure and prevent the switch from opening.

## INDUCTIVE DC LOADS

In AC circuits the voltage and current are varying in a sinusoidal pattern; both the voltage and current cross the zero reference 120 times per second for 60Hz. Therefore, probability of closing or opening a switch when the voltage and current are at their maximum in AC circuits is remote.

In DC circuits the voltage and current do not vary and are always at their rated levels.

Therefore, when opening or closing a switch on a DC load, the arc developed is more severe, more energetic, and lasts longer causing more contact erosion and a shorter switch life. A switch intended for a DC circuit should have its AC capacity rerated for DC.



Typical Tungsten Inrush Curve

## OPERATING RANGE

Three contact materials are commonly used in switches: gold, silver, and gold over silver. These materials give the options of low level, power level, plus combined power and low level ratings.

### **Low Level ~ 0.4VA maximum @ 20V AC or DC maximum**

Gold plated contacts are recommended for dry circuits, which are defined as very low energy. In circuits where the voltage is below 28 volts DC and current is below 100 milliamps (dry circuits), no arc develops as the contacts open or close. So, the tarnish remains. Eventually without the arc, the contacts become so encrusted that the switch is unable to close the circuit due to the high contact resistance. The solution to this is plating the silver contacts with gold,

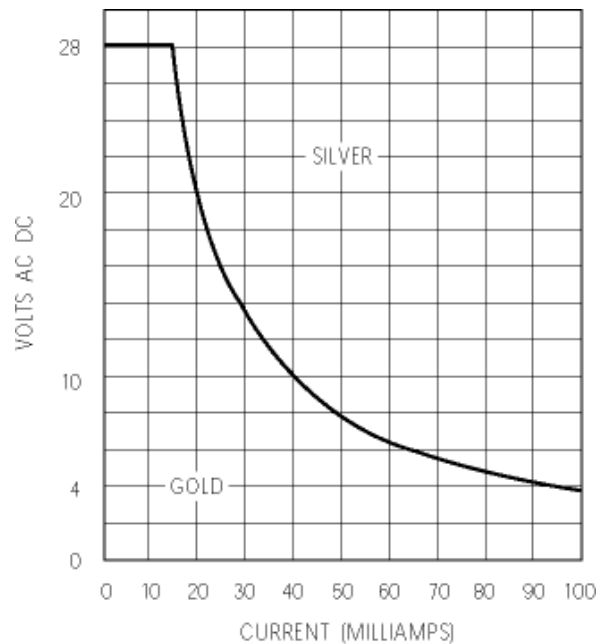
which does not tarnish. Gold plated contacts close under low voltage and low current conditions indefinitely, or for the mechanical life of the switch.

### **Power Level ~ 100mA to 10 amps @ 125V AC**

Silver contacts are recommended for electrical levels above 0.4VA. Although silver tarnishes, it is a good conductor and this electrical energy is sufficient to break through the tarnish to give reliable performance. The oxidation which coats the contact surfaces with a hard layer of insulative contamination is removed by arcing. In circuits where the voltage is above about 12 volts DC and the current above .5 amps, an arc develops during opening or closing of the contacts. This arc keeps the oxidation cleaned off.

### **Power or Low Level**

Gold over silver contacts are used in applications requiring both dry and power circuits. Gold over silver contacts have dual ratings as further described below.



### **DUAL RATINGS**

The dual rated option is suitable where identical switches are used in both a logic and a power level circuit within the same application. Dual rated switches enable the user to install the same switch in both a logic level (dry circuit) and a power level circuit.

Once a dual rated contact material switch has been used at a power level it cannot then be used at a logic level. The gold over silver contact material provides a reliable, tarnish free, contact surface for logic level switching. When a gold-placed over silver switch is used in power level circuit, the gold plating is removed by contact arcing. If an attempt is then made to use this same switch in a logic level circuit (where no arcing occurs). The low current condition cannot provide adequate contact wiping or cleaning.