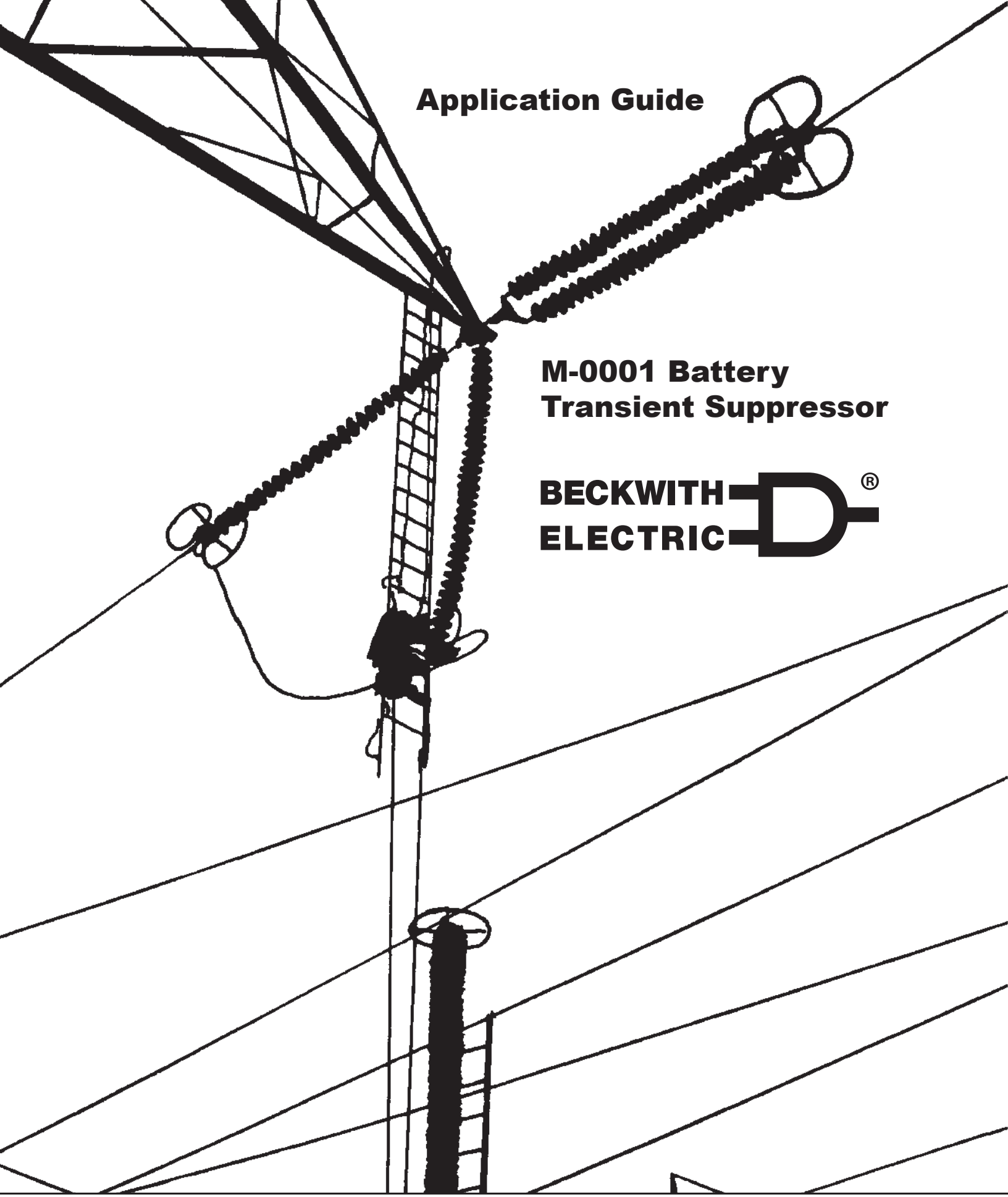
Application Guide

M-0001 Battery Transient Suppressor

BECKWITH ELECTRIC®



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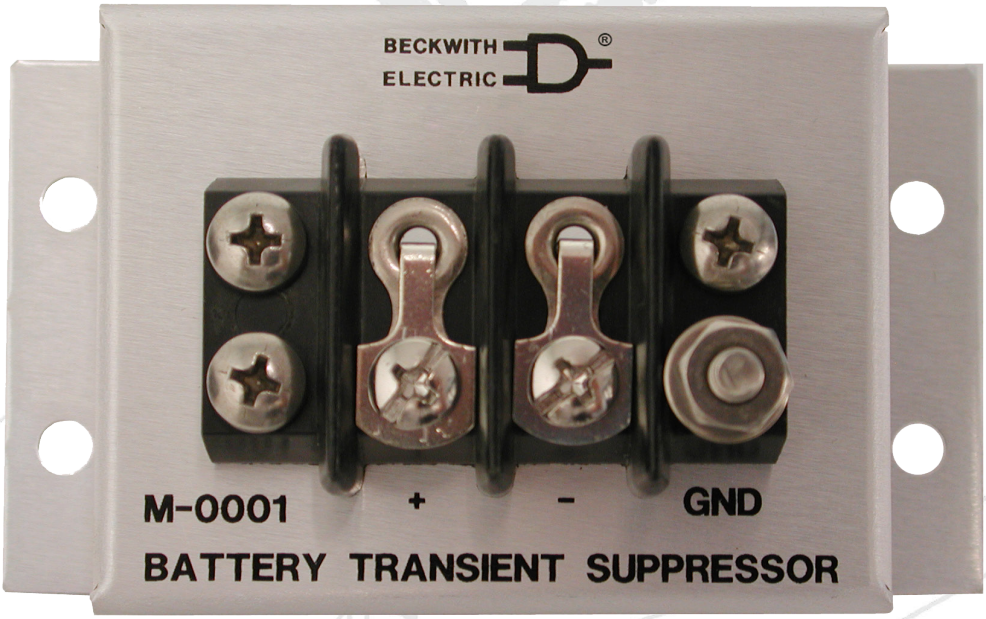
Battery Transient Suppressor M–0001



- Will not induce accidental circuit breaker tripping
- Zener diodes precisely limit the voltage to prevent reverse flow of battery current as soon as the transient is over
- Can be used on 24, 48 or 125 V batteries

Protect Against Lightning and Switching Transients and Avoid Costly Service Interruption and Equipment Damage.

Why Should You Use the M–0001 Battery Transient Suppressor?

Lightning strokes may flow through battery and control leads seeking a path to ground.

Ground faults from a power conductor can result in thousands of amperes flowing until circuit breakers operate.

Transients induced by opening air disconnects can create high frequency energy through the conductor from the switch to the first open breaker. The conductor will then act as an antenna when it is energized or de-energized, with the arc acting as a signal generator. The energy will be received by any nearby conductor.

Opening or closing a circuit breaker, especially when a power line is being switched, can cause the line to absorb the high frequency energy which can radiate to other conductors in a switchyard.

Where Should You Use the M–0001 Battery Transient Suppressor?

Use on the equipment side of battery fuses.

Why? A lightning stroke may last as long as a second. If the fuse blows early in the stroke, no suppressor will help if it is on the wrong side of the fuse.

Use one suppressor for each piece of equipment to be protected.

Why? A number of suppressors can drain off the transient energy into many paths, thereby reducing the possibility of a fuse blowing. Many suppressors cost far less than the damage that can be caused by a single lightning stroke.

Even so, a single suppressor was installed many years ago at a substation where a direct lightning stroke occurred. Although the suppressor was damaged, it protected a costly fault recorder.

Use within a few feet of the equipment to be protected.

Why? Lightning sets up high frequency resonant voltages in the battery leads. The suppressor will clamp the voltages near the equipment.

Use in place of a capacitor-type transient suppression from battery leads to ground.

Why? Control batteries are ungrounded to permit a single ground to be detected and an alarm given without causing a relay to trip. Capacitors connected to ground from the battery leads will discharge through auxiliary relays and can cause a breaker to trip on a single momentary ground.

Also use a suppressor to protect the battery charger.

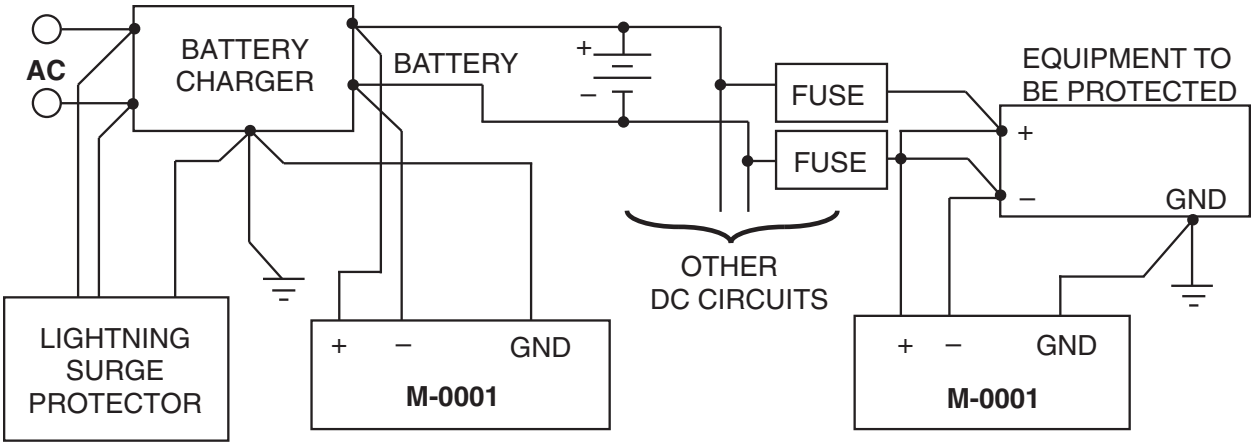


Figure 1 Battery Transient Suppressor Scheme

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BECKWITH ELECTRIC
6190 118th Avenue North • Largo, Florida 33773-3724 U.S.A.
PHONE (727) 544-2326
beckwithelectricsupport@hubbell.com
www.beckwithelectric.com
ISO 9001:2015

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1.0 Introduction

There is no simple solution to the protection of battery circuits and dc control leads from transients; the protection of each system must be engineered as carefully as the system itself. Complete protection from damage or misoperation cannot be provided by any suppressor when applied by oversimplified rules. The lack of quantitative information on transient voltages and currents makes engineering the protection scheme difficult. In addition, the problem is made more complex with the high frequency phenomenon that is associated with transients. Several devices are required which must be applied with proper fuse coordination, proper ground resistance, and proper design of associated equipment. Even so, complete protection may be limited by the amount of data available and a lack of thorough knowledge of the problem.

Properly used, the M-0001 Battery Transient Suppressor will minimize the probability of damage to and misoperation of protected equipment due to lightning, switching or line faults. Field experience with the M-0001 since 1967 shows that the unit is a reliable means of protecting valuable equipment.

2.0 Sources of Transients

There are four basic sources of transients and each has a different effect.

1. **Direct lightning strokes to *grounded* towers or bus structures:** It would seem that lightning strokes to grounded structures would not cause any damage; but in practice, there may be several reasons for damage.
   a. Ground reactance is not zero and lightning currents may flow through battery and control wires to seek a path to ground.
   b. Lightning potential may rise so fast that wave fronts of a million volts per foot are created, causing arcs seeking a short path to ground. An example of this phenomena was given by MacEchron of a "fireproof" silo, constructed of steel, that consistently burned when hit by lightning. A cross-section of the silo is illustrated in Figure 1, below.

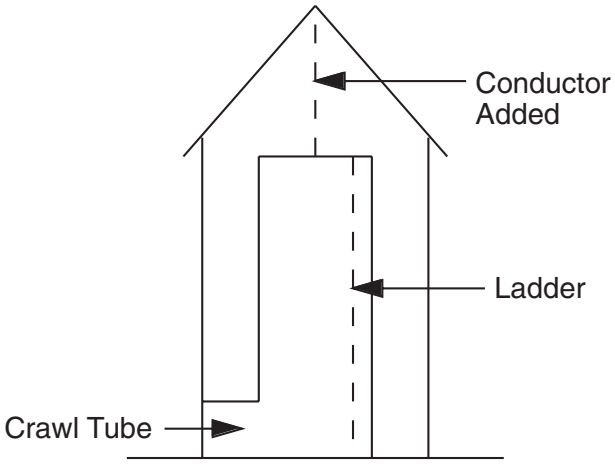


Figure 1 Fireproof Silo

The center crawl tube contained a ladder to permit access to the top portion of the silo. MacEchron reasoned that the lightning voltage built up at the top of the silo so much faster than it could travel to ground (limited by the speed of light), that an arc would strike from the inside to the top of the crawl tube. A fire would result when the contents ignited. The problem was solved by adding a conductor from the top of the crawl tube to the inside peak. The lesson learned is that a good dc ground may not be a ground at all as far as a lightning stroke is concerned.

   c. A phenomenon of lightning is that many strokes follow the predominate path of the first stroke, with hundreds of these strokes occurring during periods as long as a second. Fuses may blow in the early part of the stroke, and any suppression applied to the battery side of the fuse will not protect equipment on the other side of the fuse during the latter part of the stroke.

2. **A ground fault from a power conductor:** Thousands of amperes can flow to ground before circuit breakers operate. The path of such currents can be reasonably well predicted and their magnitudes estimated. In addition, potential drops can be calculated. The drop through the ground mat from one end of a long control cable to the other may be large, and must be considered when protection is designed for the cable and associated equipment. Since this is generally a low frequency phenomenon, the current paths may be quite different from those of lightning current.
3. **Transients induced by opening air disconnects:** High frequency energy will occur with a predominate frequency at the value where the conductor from the switch to the first open breaker is a quarter wave length. The conductor, when energized or de-energized, acts as a transmitting antenna and the arc as a signal generator. The energy will be received by any other nearby conductor. A good reason for shielding control cables is to minimize pickup of this energy by the control leads themselves.
4. **Transients induced by opening or closing a circuit breaker:** Because of the nature of these devices, the transients produced are of a shorter duration than those caused by air disconnects. The worst-case breaker operation may be in opening or closing the circuit to a bus section when no power flow occurs. Where a power line is being switched, the line will tend to absorb the high frequency energy which radiates most effectively to other conductors in a switchyard. In general, transients caused by breaker operation are small compared to lightning or ground faults, but occur more frequently.

3.0 Levels of Damage Experienced

1. In the most severe case, equipment is damaged, fuses blow and breakers misoperate.
2. In an intermediate case, damage is prevented, but fuses blow and protective relays and breakers misoperate.
3. In the least severe case, only misoperation of protective relays and circuit breakers occurs, and automatic breaker reclosing may restore the network quickly. On the other hand, it may not, and power interruptions may result.

Of course, the protection should be designed to minimize the chance that any of the above will occur.

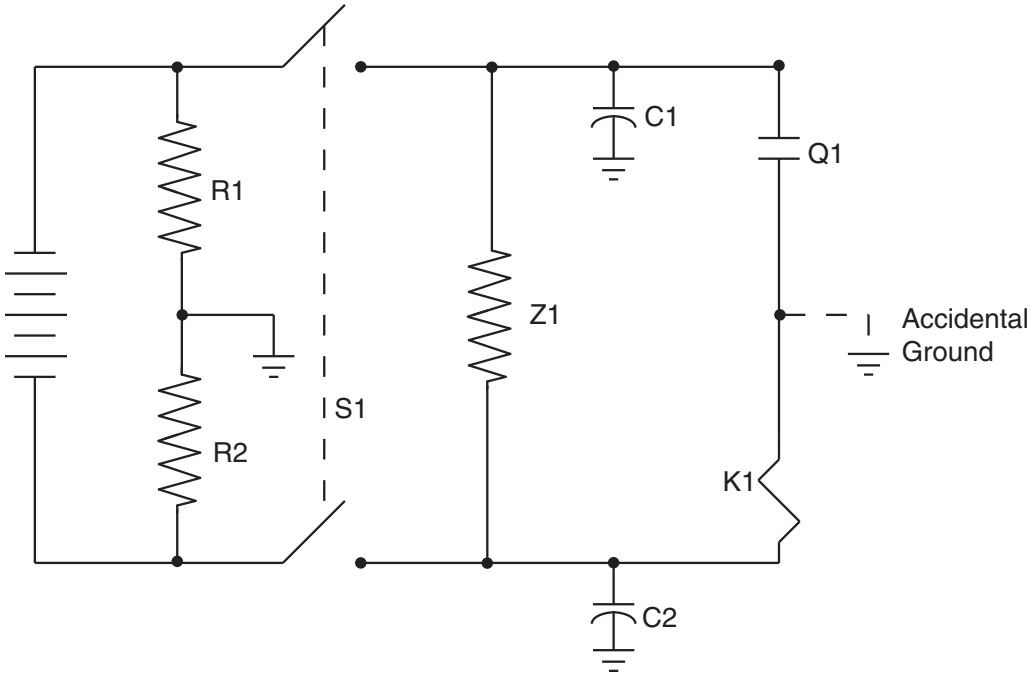
4.0 Reasoning Behind the Beckwith Electric M-0001 Suppressor

To protect against a direct lightning stroke or switching transient, either the equipment must be insulated to withstand the impressed voltage, or the lightning or transient energy must have a very direct path to ground. However, the voltage insulation levels required are generally not known, such insulation designed to estimated levels would be expensive, and equipment already exists without adequate insulation. Therefore, the latter approach seems the one with the best chance of success. The M-0001 Battery Transient Suppressor provides the direct path to ground for lightning or switching transients to protect the battery leads themselves.

Zener diodes are incorporated in the design of the M-0001 since they automatically prevent the flow of battery current as soon as the transient is over. A much more precise voltage limit is provided in the reverse direction than with other devices. Furthermore, the diodes have a turn-on time essentially that of wire; the length of the leads to the suppressor is more of a time factor than the diodes themselves. The specific diodes used have a high I^2t rating and will take a tremendous amount of current for a short time with I^2t being nearly constant from a microsecond to a millisecond pulse duration.

Series inductance, used in competitive suppressors, is not used in the M-0001 since it may resonate with stray or device capacitance and *cause* rather than suppress a transient. In addition, series inductance sets a limit on current, increases the cost of the protective device and is a further element which may, itself, fail.

The basic reason that a station battery is ungrounded is to permit a single ground to be detected without causing a false operation, especially of a circuit breaker. Therefore, capacitance from battery leads to ground is not used in the M-0001. Figure 2 illustrates how capacitors can cause false tripping of breakers.



- C1 and C2 are suppressor capacitors.
- K1 is an auxiliary relay that will operate to trip a breaker.
- Q1 is a contact that would normally operate relay K1.
- R1 and R2 are resistors in the battery ground detector.
- S1 is a battery switch that will open for a ground fault.
- Z1 is the impedance of the equipment fed by the battery.

Figure 2 DC Battery Circuit Example

When the accidental ground occurs, capacitor C2 will discharge from half battery voltage, with the discharge current flowing through K1; possibly picking up the relay for an instant. If the accidental ground does not cause the false trip, switch S1 will soon be opened in the process of finding the accidental ground. When this occurs, C1 discharges from full battery voltage through Z1 and K1. Assuming the impedance of K1 is much larger than Z1, the capacitive discharge energy that will flow into K1 is four times the amount that will flow when the ground occurred (Energy = $1/2CE^2$). There is, therefore, a greater chance of false operation of K1 when the battery switch is opened. Capacitors as small as 1 µF can pick up the breaker relays that are commonly used on a 125 V battery.

5.0 Application of the M-0001 Battery Transient Suppressor

Several basic principles are used to achieve the best chance for complete protection.

1. Lightning and switching transients set up high frequency resonant voltages in battery and other leads. To hold down this voltage, the M-0001 must be connected with very short leads to the protected equipment. For best protection, total lead length should be 12" or less.
2. The M-0001 must be connected to the equipment side of any battery fuses.
3. If possible, the battery fuses should have an I^2t rating less than 250 to prevent damage to the zener diodes used in the M-0001. Even if this is not possible, the loss of an M-0001 will be a small price to pay to protect expensive equipment or to prevent a blackout.
4. The ground connection from the terminal marked **GND** on the M-0001 should be as direct as possible. Generally, this connection should be made to the chassis of the protected equipment, with a common direct connection made from there to ground. Remember, lightning will not go around corners.

■**NOTE:** Do not expect one suppressor to protect all equipment at one location. Installation of a number of suppressors, one at each piece of equipment to be protected, allows the suppressors to share the transient current and increases the probability of surviving even a direct lightning stroke. Even so, an instance was reported where only one suppressor was installed many years ago at a substation where a direct lightning stroke occurred. The suppressor was damaged, but it protected a costly fault recorder.

Figure 3, illustrates a typical connection diagram for the M-0001 in a battery circuit. Note that Suppressor A will protect the battery charger output circuit, but is too far from any other device to give certain protection. Similarly, Suppressor B will only protect the equipment it is near (remember, near is a matter of inches).

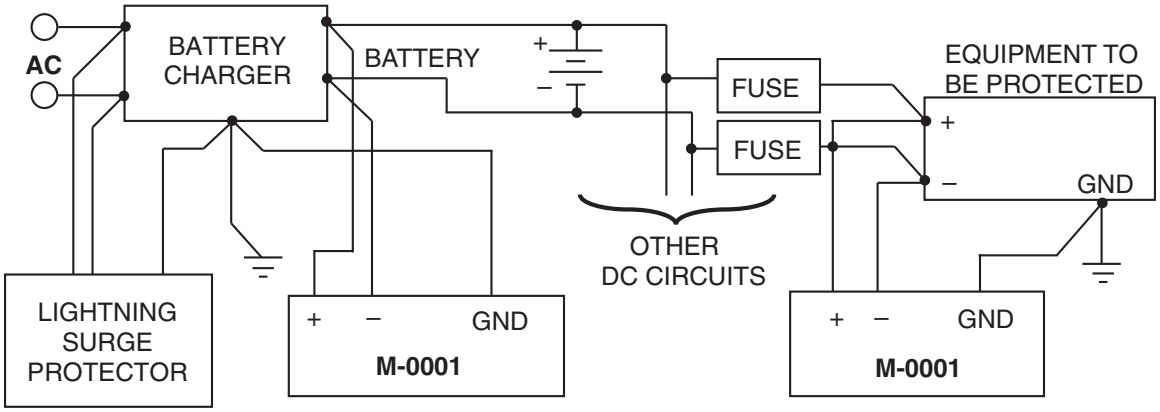


Figure 3 Battery Transient Suppressor Scheme

5. DC control leads usually connect a switching device, such as a relay contact or transistor, to an operated device, such as a relay coil. If the control lead runs some distance, transient surge voltages could damage both switching and operated devices. Figure 4 illustrates the use of protective components in a typical application.

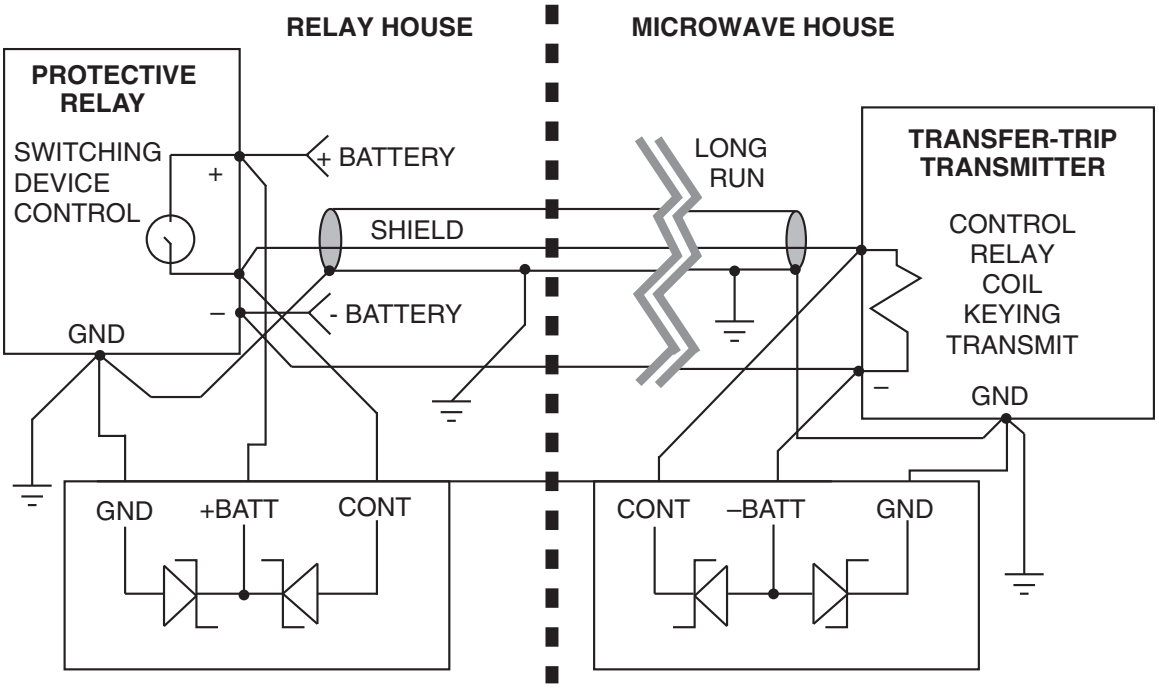


Figure 4 Control Lead Suppressor Scheme

6.0 Conclusion

Beckwith Electric has built up a background of experience in transient protection due to the wide use by electric utilities of the M-0001 Battery Transient Suppressor. In fact, Beckwith Electric products are designed to incorporate the knowledge gained by our field experience with the M-0001. For equipment that does not include such transient protection, the M-0001 is valuable insurance against damage.

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BECKWITH ELECTRIC
6190 118th Avenue North • Largo, Florida 33773-3724 U.S.A.
PHONE (727) 544-2326
beckwithelectricsupport@hubbell.com
www.beckwithelectric.com
ISO 9001:2015