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Revision B

GA-EMS CAPACITORS

CAPACITOR USER GUIDE AND SAFETY MANUAL

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GENERAL ATOMICS ELECTROMAGNETICS

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ACRONYMS

Acronym	Definition
BTDP	Benzyl Toluene Diphenyl
CO	Castor Oil
GA-EMS	General Atomics Electromagnetic Systems
PPE	Personal Protective Equipment
RSO	Rapeseed Oil
SDS	Safety Data Sheet
SO	Silicone Oil

1 PURPOSE AND INTRODUCTION

The purpose of this document is to describe the capacitors offered by General Atomics Electromagnetic Systems (GA-EMS); provide an overall framework of safe practices for handling, storing, and operation; and detail possible hazards associated with operating GA-EMS capacitors.

2 DEFINITIONS

Capacitors are devices that can accumulate and store an electrical charge on conducting surfaces separated by a dielectric.

Capacitance (C) is the ratio of the amount of charge q on one of the conductors of a capacitor to the potential difference (V) between the conductors; C=q/V.

Stored energy of a capacitor, joules (J), is a relationship between the potential and the capacitance when the capacitor is charged. $J = 0.5\ C$ (typically in microfarads, μF) * V^2 (typically in kilovolts, kV). Capacitors can store energies greater than 400 kilojoules (kJ). Stored energy of values greater than 10 J is considered a hazard, and greater than 50 J is considered potentially lethal.

3 CAPACITOR TYPES

GA-EMS manufactures both metal (welded and drawn) case and plastic case capacitors. GA-EMS also designs and manufactures custom capacitors that do not fall into the pre-set family categories.

3.1 Plastic Case Capacitors

Plastic case capacitors come in two standard configurations: single-ended and double-ended. Single-ended capacitors are characterized in Figure 1, and double-ended plastic case capacitors are characterized in Figure 2.

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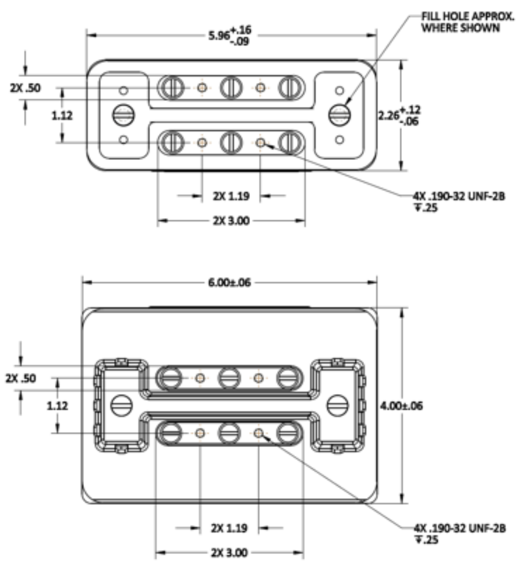
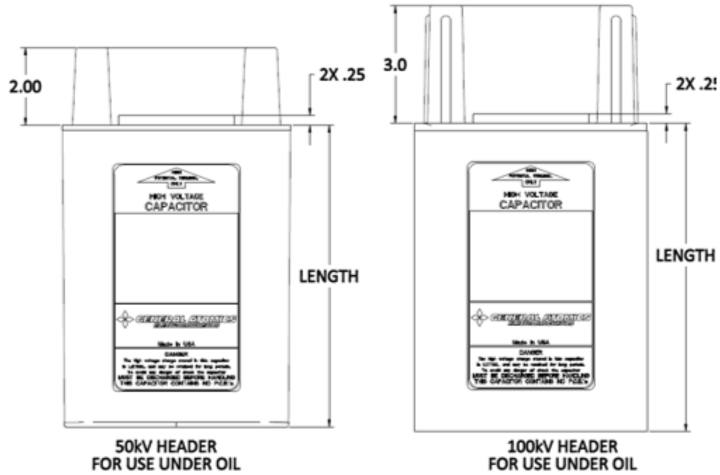
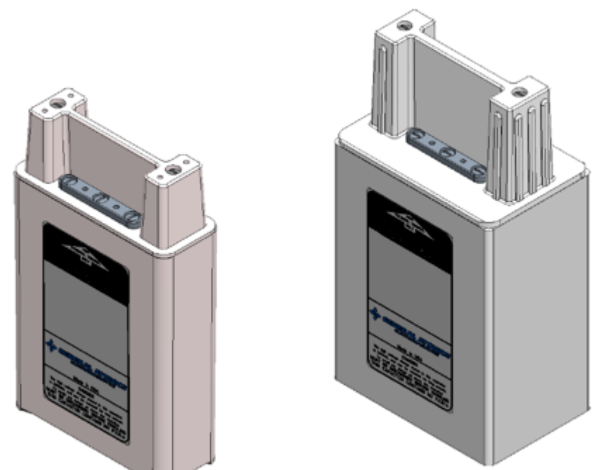




Cross Section	Approx. Weight (lbs)
2.3" × 5.9"	0.78 × Length (in)
4.0" × 6.0"	0.95 × Length (in)



4.0" X 6.0"

2.3" X 5.9"

Figure 1. Physical Characteristics of Single-Ended Plastic Case Capacitors

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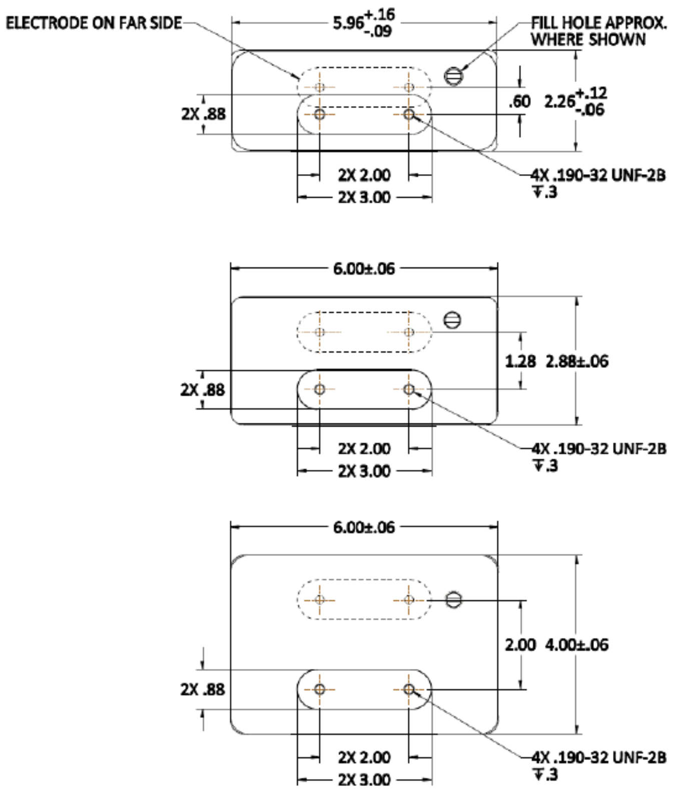

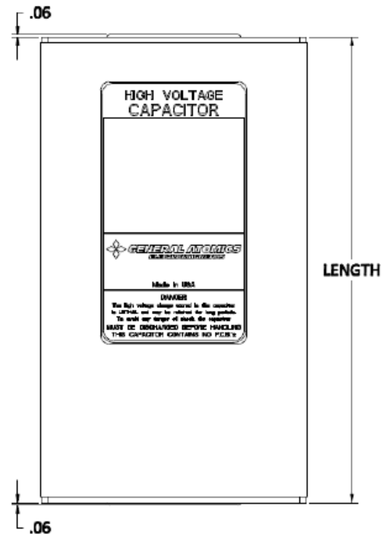

Cross Section	Approx. Weight (lbs)
2.3" × 5.9"	0.78 × Length (in)
2.9" × 6.0"	0.84 × Length (in)
4.0" × 6.0"	0.95 × Length (in)

2.3" × 5.9"   2.9" × 6.0"   4.0" × 6.0"

Figure 2. Physical Characteristics of Double-Ended Plastic Case Capacitors

3.2 Steel Case Capacitors

Steel case capacitors typically are much larger than plastic case capacitors. These capacitors are offered in painted carbon steel cases or unpainted stainless-steel cases. Given the large range of voltages (2.5 – 120 kV), there are many different bushing and electrode types for these capacitors.

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3.2.1 Scyllac Style Bushing

Scyllac bushings come in two configurations: low-barrier and high-barrier. The difference between these two configurations is their voltage ratings, listed in Table 1. The electrode internal to the Scyllac bushing is 3 inches in diameter and has a 1.000-14 UNF-2B threaded hole, 0.75 inches deep. This bushing/electrode configuration can be used up to 250 kiloamperes (kA) peak current.

Table 1. Scyllac Voltage Ratings

Scyllac Bushing Configurations	Voltage Rating in Air (kV)	Voltage Rating in Oil/Dielectric Gas (kV)
Low-Barrier	40	60
High-Barrier	60	110

Physical dimensions of the low-barrier and high-barrier Scyllac bushings are outlined in Figure 3.

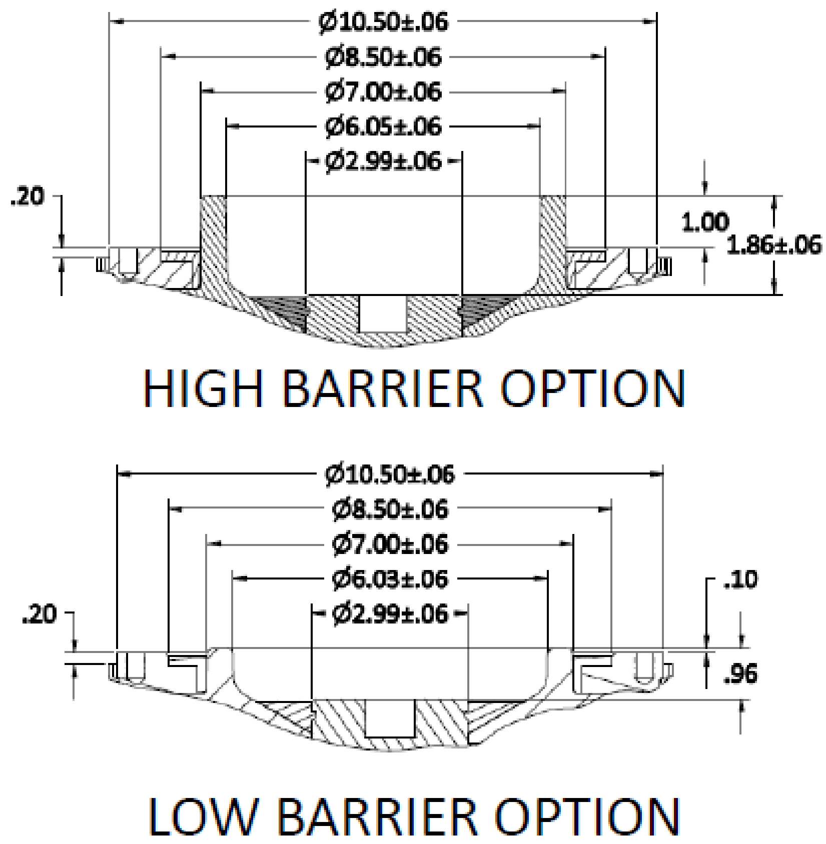

Figure 3. Scyllac Bushing Configurations

Capacitors with Scyllac bushings use a case return for ground, and ring around the bushing can be used for both ground and installing eyebolts for handling.

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3.2.2 Low-Profile Bushings

GA-EMS uses three different types of low-profile bushings. The LP25 bushing has a 5-inch outer diameter, the LP50 bushing has a 6.5-inch outer diameter, and the LP60 has a 7-inch outer diameter. The number after the "LP" is the rated voltage that the bushing can handle (in kilovolts) and does not indicate the voltage rating of the capacitor. The capacitor label should be referenced for the capacitor's rated voltage. Each bushing can be fitted with a 0.750-16 UNF-2A threaded electrode, and the LP25 and LP50 can be fitted with a 0.500-13 UNC-2A electrode. The 0.500-13 UNC-2A electrode is rated to 100 kA current discharge, and the 0.750-16 UNF-2A electrode is rated to 150 kA discharge. Details are outlined in Figure 4.

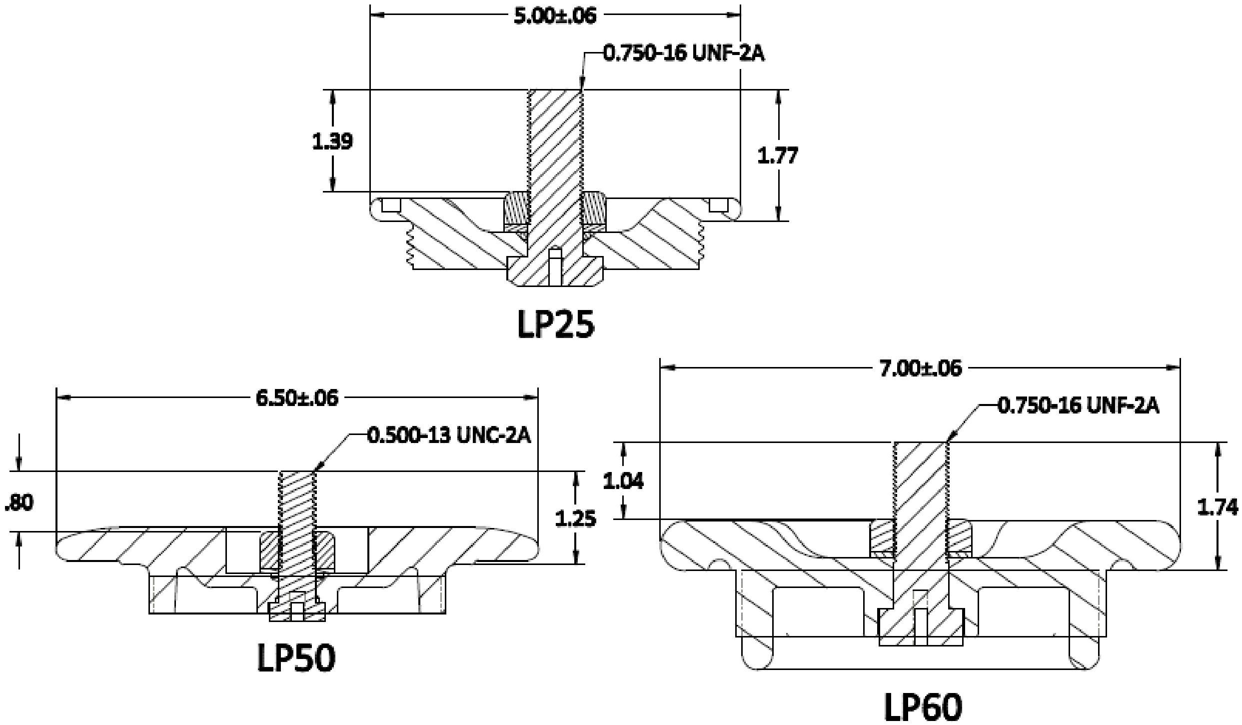

Figure 4. Low-Profile Bushings

Capacitors with low-profile bushings can come in one- , two- , and four-bushing configurations. In the one-bushing configuration, a case return is used and the weld nuts on the cover of the capacitor are used for both ground and installing eyebolts for handling. In the two- and four-bushing configurations, the bushing's polarity is marked and the case floats electrically.

3.2.3 Upright Ceramic Bushings

GA-EMS can use many different configurations of upright ceramic bushing depending on the voltage rating of the capacitor. Ceramic bushings are hermetically sealed to the capacitor. Ceramic bushings are fragile, and excessive forces applied to the bushing can cause them to break. Weld nuts are installed onto the cover of these capacitors for safe handling.

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4 LABELING AND INFORMATION

Capacitors manufactured by GA-EMS are labeled to provide useful information to customers. Capacitors intended for use in air have a polyester label placed on the side of the capacitor with an adhesive backing. Examples of these are shown in Figure 5.

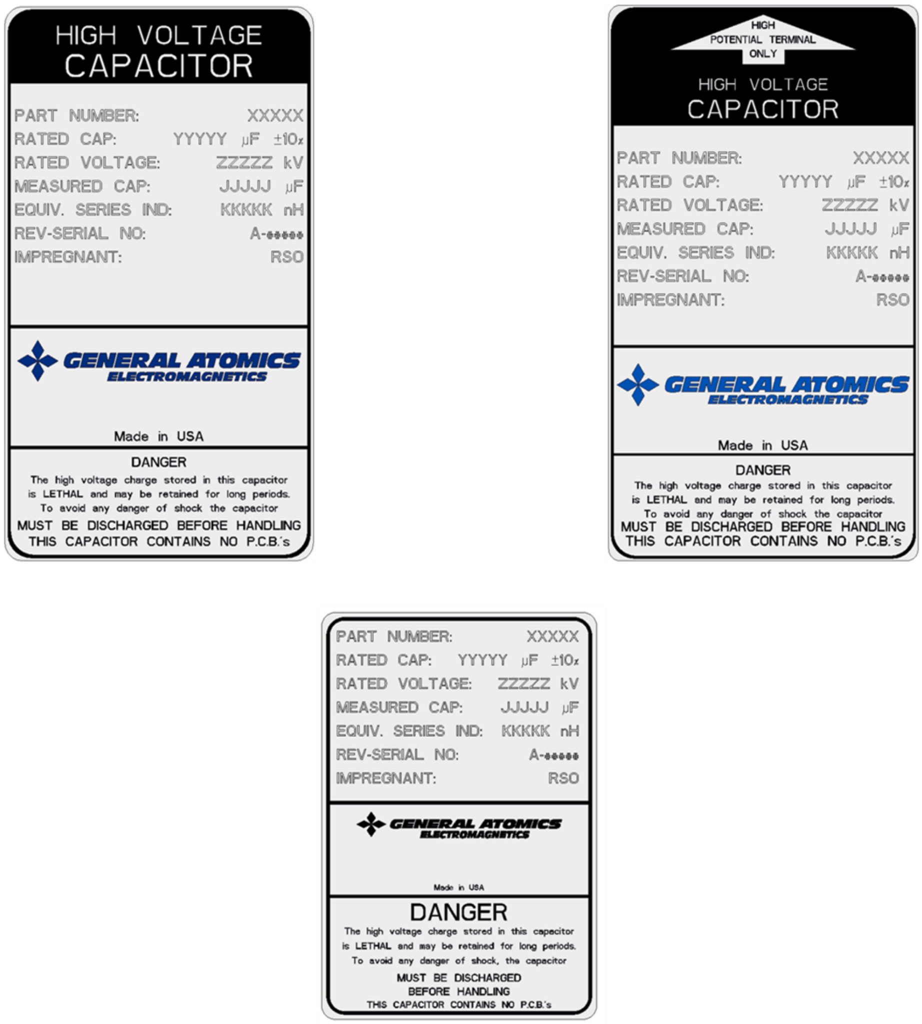

Figure 5. Examples of Labels

Capacitors intended for use under oil have the marking information etched into the face of the capacitor, with the label taped over it and the backing still attached, or stamped onto the case of the capacitor.

See Table 2 for capacitor labeling information.

Table 2. Capacitor Label Information

Label	Example	Definition
Part Number	XXXXX	GA-EMS part number for the capacitor
Rated Capacitance	YYYYY µF ± 10%	Nominal design capacitance of the capacitor and tolerance

Rated Voltage	ZZZZZ kV	Rated voltage of the capacitor
Measured Capacitance	JJJJJ µF	Measured capacitance of the capacitor
Equiv. Series Ind.	KKKKK nH	Equivalent series inductance of the capacitor
Rev-Serial Number	A-#####	Revision of the design and serial number of the capacitor
Impregnant	RSO	Impregnant of the capacitor GA-EMS uses Rapeseed Oil (RSO), Silicone Oil (SO), Benzyl Toluene Diphenyl (BTDP), Castor Oil (CO) in its capacitors. Safety Data Sheets (SDSs) available upon request.

5 HANDLING

High-voltage capacitors should always have a shorting wire in place while handling the device. Capacitors should always be considered energized unless a shorting wire is present between the terminals of opposite polarity, between the terminal and the case, or between the terminal and another grounded location. When a capacitor must be relocated, it is essential to ensure that the capacitor is fully discharged by touching a shorting stick with a high energy resistor to each terminal and the case of the capacitor and connecting a shorting wire. Shorting wires should be applied or removed using the one-hand method.

Plastic case capacitors have a maximum weight of 30 pounds and can be carried by hand following safe lifting and carrying procedures. It is recommended that these devices be carried or handled with two hands, as the cases can be slippery. Dropping a plastic case capacitor, even from a short height, can result in a fracture of the case and leakage of the internal dielectric fluid.

Steel case capacitors have lifting points attached, and eyebolts along with heavy lifting equipment need to be used to handle or move these capacitors. Never lift a capacitor by the shorting wire, bushings, or electrodes, as this could result in a hazardous situation or case rupture. Large steel case capacitors also serve as possible tip hazards; care should be taken in transporting or moving a large capacitor that may weigh as much as several hundred pounds.

Unless specially designed, capacitors are not rated to particular transportation, vibration, or shock ratings.

Consult GA-EMS if intending to operate capacitors in alternative orientations. Operation in an inverted condition can result in internal assemblies compressing buswork. Typically, operation of a capacitor on its side is permissible, though care must be taken for handling and voltage clearances.

6 TRANSPORTATION

It is recommended that transportation of devices be done with secondary containment, typically in the form of foam-filled, wooden, or plastic containers, with capacitors securely positioned

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within. Failure to secure the capacitors within the case can result in devices colliding with case walls and each other. It is not recommended to package capacitors with just packing peanuts/ foam pieces. As stated above, the capacitors should be transported with terminals shorted.

7 STORAGE

Capacitors shall always be stored shorted so that energy cannot build up in the device spontaneously. Storage requirements vary by capacitor. In general, most capacitors are designed to withstand ambient temperatures between -20 and +65 °C. Capacitors should be secured to prevent tipping. Capacitors can be stored upright or on the long side. Contact GA-EMS with specific storage concerns.

8 PROPER USAGE

GA-EMS capacitors are rated for use at specific voltages, currents, voltage reversal, and pulse rate. Exceeding these ratings voids the warranty and greatly reduces the expected life of the device. In some cases, exceeding the ratings of the capacitor could result in catastrophic failure of the device, as detailed in Section 9. Capacitors can be operated upright or on their side. The high potential electrode is on the label side on plastic single ended cases, at the end nearest the top of the label on plastic double-ended cases, and the upright terminal on the right side of a metal case capacitor when the case is not the ground return.

9 CAPACITOR HAZARDS

High-voltage capacitors, such as those manufactured by GA-EMS, can present a number of hazards to personal safety.

9.1 Electrical Shock

Interaction with capacitors can lead to exposure to lethal amounts of current and high voltage. Always assume that a capacitor has energy stored within when about to handle and take precautions to discharge. These precautions should consider the amount of energy stored, available shorting equipment, paths to ground, and Personal Protective Equipment (PPE). An improperly selected resistor can result in flash-over, shock, or explosion of the resistor.

Once discharged, apply a shorting wire across the high-voltage terminal and ground. High-voltage capacitors are capable of self-recharging to a small percentage of their original charge voltage; this shorting wire will help prevent such recharge. Proper electrical PPE should be worn when operating high-voltage capacitors.

9.2 Arc Flash and Arc Blast

Arc faults can occur during capacitor usage if the voltage potential in the capacitor system breaks down. This can occur through air, insulative material, or failure of the intended conductive path. Arc flash is the light and heat created from an arc fault. Arc flash can be several thousands of degrees and ignite clothing or burn skin within a few feet. Arc blast is the

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pressure wave created from an arc fault. Proper circuit design, stand-off distances, and PPE should be used when discharging a capacitor. Note that overvoltage of plastic case capacitors could cause an arc through the plastic case of the capacitor.

9.3 Proximity Arcing and Short-Circuits

It is important to consider clearance distances and creepage distances in system design when using high-voltage capacitors. An arc discharge to a case next to the terminal can be caused by improperly maintained cleanliness or by improper clearances and gaps. These sorts of faults can be catastrophic in large banks, as other capacitors may participate in the discharge. Even an individual capacitor participating in a short-circuit discharge can result in irreparable damage to internal buswork, cases, and surrounding environment.

9.4 Explosion

There are several issues that can cause a capacitor to fail catastrophically in an explosive manner, releasing internal pressure and resulting in case rupture. These include but are not limited to overvoltage, buildup of internal pressure, overcurrent, and breakdown of the dielectric material or insulation inside the capacitor. In some situations, the explosion can be followed by a fire, as the dielectric fluid is ignited and spills from the capacitor (discussed in Section 9.5). In the event of an electrical explosion, turn off the power supply of the device. Once the device and surrounding area are determined to be safe, the capacitor should be shorted and disposed of.

9.5 Burn/Fire

Some failure modes of capacitors can cause excessive heat, which can turn into a fire if placed near a flammable component. In addition, some capacitors contain a Class III-B liquid which can ignite if there is a case puncture or rupture in the presence of an electrical arc. Thermal and electrical PPE should be used when handling capacitors that were previously in use.

9.6 Hazardous Materials

Several materials internal to a capacitor can be classified as hazardous. These include but are not limited to lead used in solders, zinc electrodes, and several of the dielectric fluid GA-EMS employs in its capacitors. Material SDSs are available upon request.

10 DISPOSAL

Capacitor disposal is controlled by laws present in the country of operation of the devices. Contact GA-EMS for material SDSs required for disposal.

11 CONCLUSION

Customers purchasing GA-EMS produced capacitors should follow the handling and hazardous material best practices described by Federal standards and read and ensure comprehension of all GA-EMS produced documents relating to the purchased capacitor. This includes all SDSs, handling procedure recommendations, and PPE requirements.

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