Paper and Film Energy Discharge Capacitors: An Introduction

by
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INTRODUCTION

Astronaut Michael Collins peered out of the docking window of the Apollo command module , the Columbia. A flashing strobe brilliantly indicated the position against the Moon's surface of the lunar module ascent stage, the Eagle. It carries Astronauts Neil Armstrong and Edwin Aldrin, Jr. back from the Sea of Tranquility in July 1969. The rendezvous completes mankind's greatest exploration.

At a family reunion, the grandfather collapses. Emergency paramedics arrive on the scene, reviving the stricken man with a portable heart difibrillator. Flashing lights atop the vehicle warn motorists to give way as it speeds the man away from medical treatment.

A couple walk along a bayshore at dusk. Dancing red, blue and white lights cast ethereal reflections across the harbor. They are beacons of safety, warning approaching aircraft of skyscrapers, watertowers, and communications antennae.

The forward spotter of the NATO "Blue Army" directs his artillery unit's firepower at an approaching "enemy" armor group during war games. The powerful beam of his hand-held laser range finder penetrates the haze and smoke of the mock battlefield. Fusillades pulverize the armor group with unmatched precision.

A secretary reproduces the annual plan of a Fortune 500 company for a hastily called board meeting. The brilliant light of the office copier creates crisp, high resolution documents at an astonishing pace.

How are these examples of modern technology made possible? What is the heart of each complex system? The answer is the energy discharge capacitor, also referred to as energy storage capacitors. They play an important role in our lives today.

Many papers and articles have appeared acclaiming the virtues and warning of the shortcomings of ceramic, tantalum, aluminum electrolytic and film capacitors which operate in steady state direct current circuitry or in high frequency alternating current applications. Relatively few have discussed the paper or film energy discharge capacitor which is the subject o f this paper. After charging, the energy discharge capacitor is held at the operating voltage for some time period, after which it is discharged in fractions of a milisecond. The resulting discharge energy pulse achieves very high instantaneous power used to perform various tasks. Thus the name. by proper dielectric selection, the available energy can be higher than eight joules per cubic inch or about one hundred forty joules per pound. With special design considerations, discharge currents higher than one thousand amperes at duty cycles in the range of one per second can be attained. When used in stationary installations the capacitor size and weight is not of singular importance; but one portability is required, these factors and the case of mounting become critical. This paper is an attempted to acquaint the unfamiliar with the paper and film energy discharge capacitor and to provide a refresher course for the experienced capacitor user.

1	2	3	4	5	6	7	8
Dielectric Class	**Dielectric Type**	**Dielectric Constant (K)**	**Specific Gravity (g/cm^3)**	**Breakdown Voltage (VDC/mil)**	**Relative Energy by volume***	**Relative Energy by wieght****	**Operating Temp. Max. (ºC)**
Plastic Films	Polycarbonate (PC)	3.0	1.20	4.500	60	51	125
	Polypropyelene (PP)	2.2	0.92	14.750	478	218	105
	Polyester (PETP)	3.3	1.40	13.250	579	414	85
	Polyvinylidene Diflouride (PVF_2)	9.5	1.76	10.000	950	540	125
	Polyphenylene Sulfide (PPS)	3.0	1.35	9.000	243	180	200
	Teflon (PTFE)	2.1	2.20	7.400	115	52	200
Paper Impregnated w/	Polyisobutylene	3.0	1.20	4.350	57	47	125
	Mineral Oil	3.1	1.20	4.150	53	45	85
	Silicone Oil	3.6	1.20	3.250	38	32	125
	Mineral Wax	3.1	1.20	3.300	34	28	125

* $K (V/mil)^2 \times 10^{-6}$
** $K/g/cm^3 (V/mil)^2 \times 10^{-6}$

Energy Discharge Capacitor Dielectrics

First, a summary and discussion of the dielectric types used in energy discharge capacitors is in order.

There are four important factors when selecting a dielectric. They are: 1) the dielectric constant, 2) the dielectric breakdown voltage, 3) the dielectric's operating temperature range, and 4) the dielectric's loss. The first of these directly impacts the size of the final capacitor. The second affects the size and also the capacitor's reliability or life expectancy. The third determines what dielectrics are appropriate for the application depending on capacitance and voltage rating. The fourth determines the maximum current rating.

Table 1 lists the major plastic and paper dielectric types which are considered when designing an energy storage capacitor. Voltage breakdown data was obtained on samples of these dielectrics experimentally and form the manufacturer's literature. Comparisons can be made between these dielectrics if one assumes that the effect of margins and dielectric thickness, are constant. This comparison is given in Table I.

Energy Density

Let's assume that the rated voltage of a capacitor is approximately proportional to the breakdown voltage of the direlectric used. A figure of merit for the maximum energy per cubic inch for a dielectric system can e obtained by multiplying the dielectric constant(k) by the square of the dielectric's breakdown voltage. See Column 6 of Table I.

If the values computed for the maximum rated voltage of a dielectric in Column 6 are divided by the dielectric's specific gravity or density, a figure of merit for the maximum energy-per-pound can be obtained. See column 7.

Performance Characteristics

The optimum size efficiency is obtained by using plastic film dielectrics, more specifically polyvinylidene difluoride followed by polyethylene terephthalate, hereafter referred to as polyester. Impregnated paper dielectrics have relatively low figures of merit compared to the plastic films. So why aren't all energy storage capacitors made with these two plastic films?

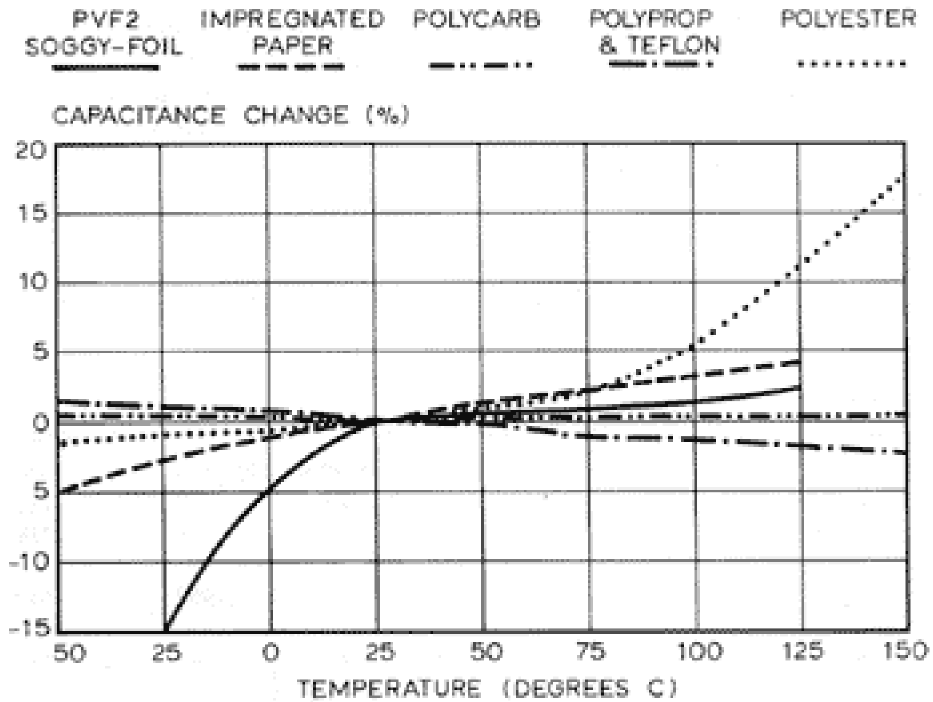
One reason is because polyvinylidene difluoide experiences a dramatic loss of capacitance when the operating temperature drops below zero degrees centigrade. Graph 1 illustrates the effect of temperature on capacitance for dielectric types. This is important when considering the direlectric choice for an energy discharge capacitor, since the available energy in joules equals one-half of the product of the capacitance and the square of the operating voltage. Polyethylene erephthalate, on the other hand, does not have this capacitance loss as a result of temperature, but has another serious drawback. At approximately 85 degrees centigrade it experiences a dramatic increase in dissipation factor. This is a serious shortcoming when designing energy discharge capacitor is directly proportional to the product of the rms current squared ad the resistance. Graph 2 illustrates the effect of temperature on the dissipation factor at a frequency of the one kilohertz.

E = ½ (CV2)

Polycarbonate, which has a similar dielectric constant to polyester and superior dissipation factor performance over a broader temperature range, ahs the disadvantage of the lowest breakdown voltage.

The major disadvantage of polypropylene is its comparably low dielectric constant which limits energy density.

Polyphenylene sulfide (PPS), relatively new on the scene of film capacitor dielectrics, may offer advantages of high operating temperatures similar to Teflon (PTFE) but with superior size efficiency, resulting from its higher dielectric constant and breakdown voltage.



GRAPH #1

CAPACITANCE VS TEMPERATURE

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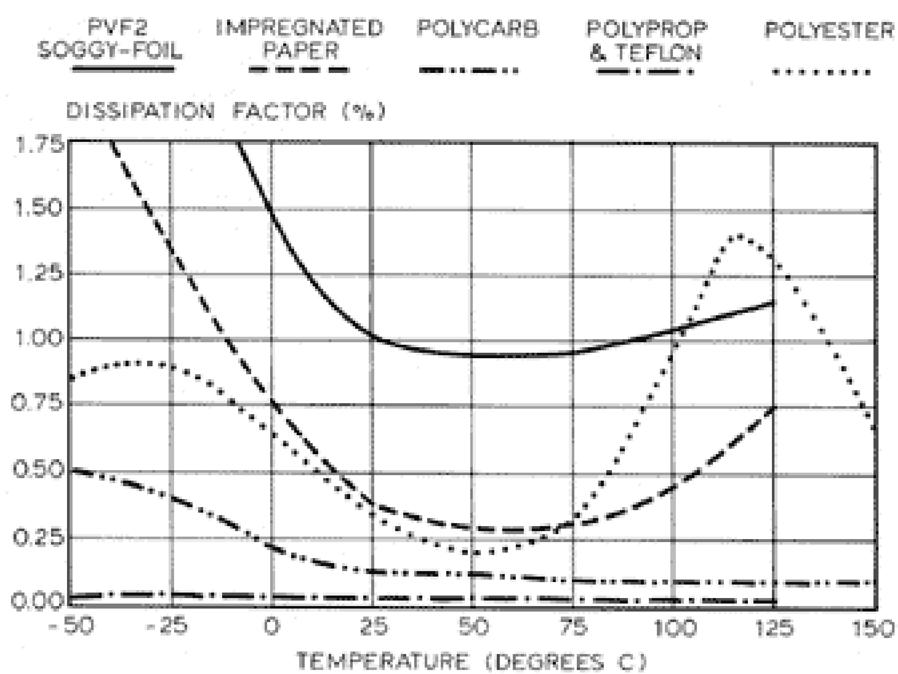

GRAPH #2

1KHz DF VS TEMPERATURE

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ENERGY DISCHARGE CAPACITOR DESIGN CONSIDERATIONS

Unlike conventional DC capacitors which are used at a steady DC voltage in filtering, by-pass and like applications, energy discharge capacitors are designed specifically for applications which involve varying period so intermittent duty or on/off cycles between charging and discharging.

This intermittent use permits the capacitor to be designed for operation at a higher dielectric stress in volts per mil than would be advisable for steady state DC operations. This gives the energy discharge capacitor a size advantage at ht same voltage rating compared to steady state designs. Still, the design must be robust enough to withstand the repeated current pulse on discharge.

Current Stress

The ability to reduce size and achieve high energy density results in a high peak current stress on the capacitor end connection, in terms of amps per linear inch of active dielectric. If the current stress of the application is severe, the advantage of reduced dielectric thickness to achieve high energy density may be forsaken. The length to diameter ratio may also be tailored to achieve an acceptable amp per linear inch value, if allowed by the application dimensional requirements. While the limit of the current carrying capability of the metallized energy discharge capacitor has yet to be determined, values of 0.10 to 0.25 amps per linear inch have generally been accepted by the industry. This is quite small when compared to several amperes per linear inch achievable with extended foil designs. In general, the larger the length to diameter ratio, the greater the joules per cubic inch, but the lower the current carrying capability.

The ultimate current carrying capability is also determined by the type of end connection selected by the designer for the application. There are two basic types. They are: a) metallized extensions of aluminum or zinc layers which have been deposited directly to the dielectric's surface with thicknesses on the order of hundreds of angstroms (Figure 1), and b) extended discrete metal foils, typically aluminum (figure 2). Each of these have advantages and disadvantages. The choice may not only affect the current carrying capability of the energy storage capacitor but its life, reliability and size.

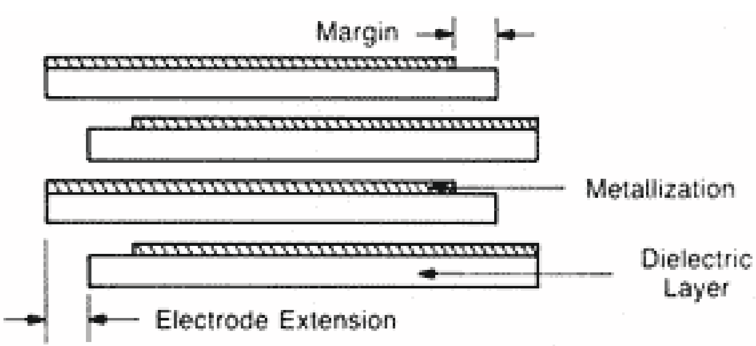

Figure 1
Metallized Construction

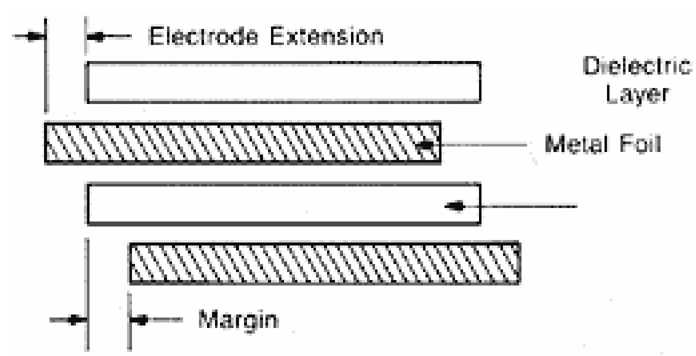

Figure 2
Foil Construction

Voltage Stress

Energy discharge capacitors constructed with metallized electrodes are smaller, lighter and have a greater energy density than those using discrete metal foils this is because the weight and diameter of the wound capacitors element is much smaller than comparable designs using discrete metal foils. In addition, the metallized design can be operated at much higher voltage stresses, which allows the use of thinner dielectric layers. These factors contribute to the higher energy density of metallized designs.

The high voltage stress of the metallized design is the result of the "selfhealing" or "clearing action" which takes place when a fault or momentary short circuit occurs in the dielectric. Clearing takes place when a shorting current vaporizes and removes the metallization in the immediate vicinity of the breakdown in the dielectric. The vaporization of electrode continues, ideally in a circular pattern, until the current path at the point of the breakdown becomes too great, stopping the short-circuiting between electrodes. While this clearing action is beneficial, in that the capacitor returns to an operable condition almost instantaneously, it has a major drawback in high energy capacitors. The resulting deterioration of the dielectric in the immediate area adjacent to the fault, if severe enough, could trigger additional breakdown points which would in turn clear and so on. This chain reaction or avalanche is signaled by a loss of capacitance and low insulation resistance, leading eventually to the inability to store the desired energy or to a short circuit. If the avalanche takes place near the end connection, an open condition may occur. This avalanche phenomenon does not occur in conventional metallized capacitors of voltage less than 1000 and capacitances less than 10°F, where the clearing action is nondestructive.

For about the last twenty years, Sprague Electric has been supplying a composite dielectric system which, to a large extent, inhibits its damaging clearing effect. By coating polyester with a proprietary lacquer, a metallized energy discharge capacitor can e constructed which allows an effective clearing action to take place that does not have th deleterious carbonization and destruction polyester alone (Figure 3). This proprietary film allows a higher voltage stress, and thus capacitors of higher energy density than could be otherwise achieved, When a clearing takes place, both the metallization and the coating are vaporized from the area adjacent to the fault, but the puncture hole in the polyester is kept to a minimum.

A useful dielectric configuration for high voltage applications is to convolutely wind together plain plastic and metallized paper dielectrics to form a multi-layer capacitor winding. These windings are then usually impregnated. This construction type takes advantage of high breakdown strength and dielectric constant of the plastic, the clearability of metallized paper and the wicking action of the impregnant throughout the paper to further enhance the breakdown voltage (Figure 4).

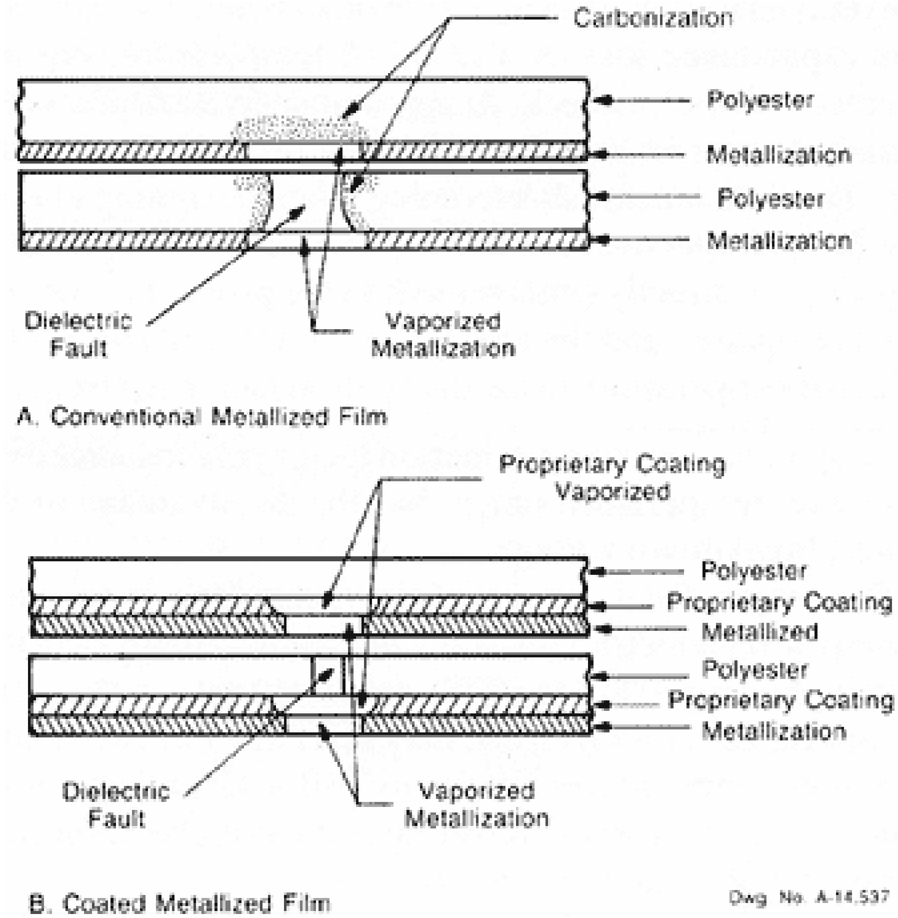

Figure 3
Metallized Capacitor Cross Section

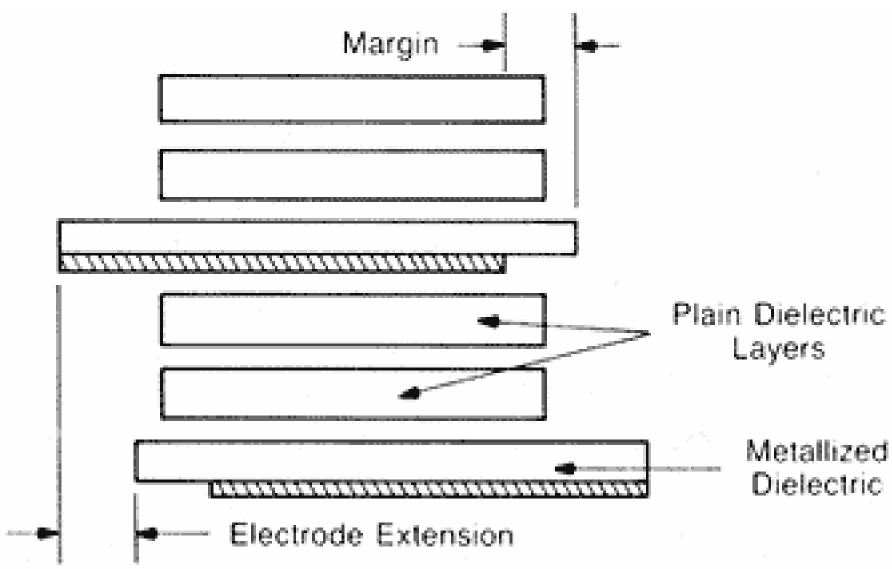

Figure 4
Multi-Layer Construction

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Life

When the application requires an extremely long life (e.g. 100 million discharge cycles), the extended metal foil construction has an advantage since it is not prone to the eventual end connection deterioration from clearing. The foil design does not, however have the advantage of self healing when a dielectric fault occurs since the foil cannot be vaporized. Thus, foil designs generally use thicker dielectrics, sacrificing energy density.

The extended foil designs also improves the thermal conductivity of the capacitor, since the metal foils act as heat sinks and draw the heat out from the interior. The superior heat dissipation of the metal foil designs also reduces dielectric degradation due to thermal aging which has a major impact on capacitor life. The foils also allow the capacitor to operate at higher peak currents and operation at faster duty cycles. The thermal conductivity of the metallized design can be improved by filling or impregnating with a liquid dielectric such as silicone or mineral oil, but even this does not approach the heat dissipation efficiency of solid foil conductors.

Another type of end connection and dielectric configuration is the "soggy-foil" construction. This design attempts to marry the advantages of the metallized film and extended foil. "Soggy foil" is paper dielectric tissue which has been metallized on both sides. The double metallized paper is wound into the capacitor in the same manner as a metal foil and the capacitor is impregnated (Figure 5). The end connection is effectively doubled in comparison to the extended metallized film design, and the metallization can clear on the paper resulting in minimum damage to the dielectric film. The paper is not I the active capacitor layers or field

The Energy Discharge

First, let’s consider the importance of the capacitor’s resistance. The heat generated within the capacitor during operation is equal to the product of the capacitor’s equivalent series resistance (R) and the square of the rms current (I).

Equation 1

$$\Delta H = I^2 R$$

If heating becomes too severe, it decreases capacitor life; but if the resistance is allowed to become too high, it will reduce the peak current value at discharge.

Very little can be done about the current since it is an application requirement, so resistance must be controlled by the designer. A reduction in film width is a design option when the contribution of the electrodes and termination resistance must be minimized. Again, this sacrifices energy density. An alternative approach to reducing the resistance of the capacitor to attach two separate windings in parallel. This parallel design also offers the added advantage of reduced inductance.

The current pulse duration (in seconds) at discharge is given by the product of pi and the square root of the product of the capacitor’s inductance (L in henries) and value (C in farads).

Equation 2

$$t = \pi\sqrt{LC}$$

Typically, energy discharge capacitors release their stored energy into a load of less than two ohms, for example, Xenon flash tubes. In many applications an inductor is placed in series in the discharge circuit to shape the current pulse for specific requirements.

and acts only as a carrier for the metallization and the impregnant.

Regardless of the termination technique and dielectric configuration selected, the inductance and series resistance of the energy discharge capacitor must be kept to a minimum. Both are affected by the final geometry, internal construction and external terminal placement of the final capacitor package. Why are these two factors important? They directly affect the parameters of the discharge pulse as wee shall see in the next section.

When the energy is released, two types of current pulses may occur which are dependent on the inductance of the discharge circuit containing the capacitor. They are oscillatory and non-oscillatory. The oscillatory discharge is characterized by several voltage peaks during the release of energy to the load (Figure 6). This type of discharge is the most severe form of duty for an energy discharge capacitor because of the oscillating frequency (ringing) and voltage reversal. (Please note that references to exp. In the following equations indicate e, the natural logarithm.)

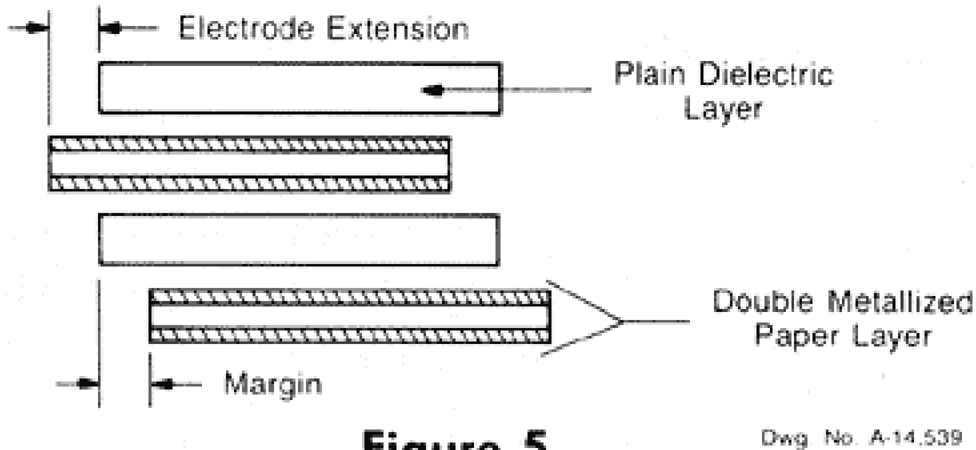


Figure 5
Soggy-Foil Construction

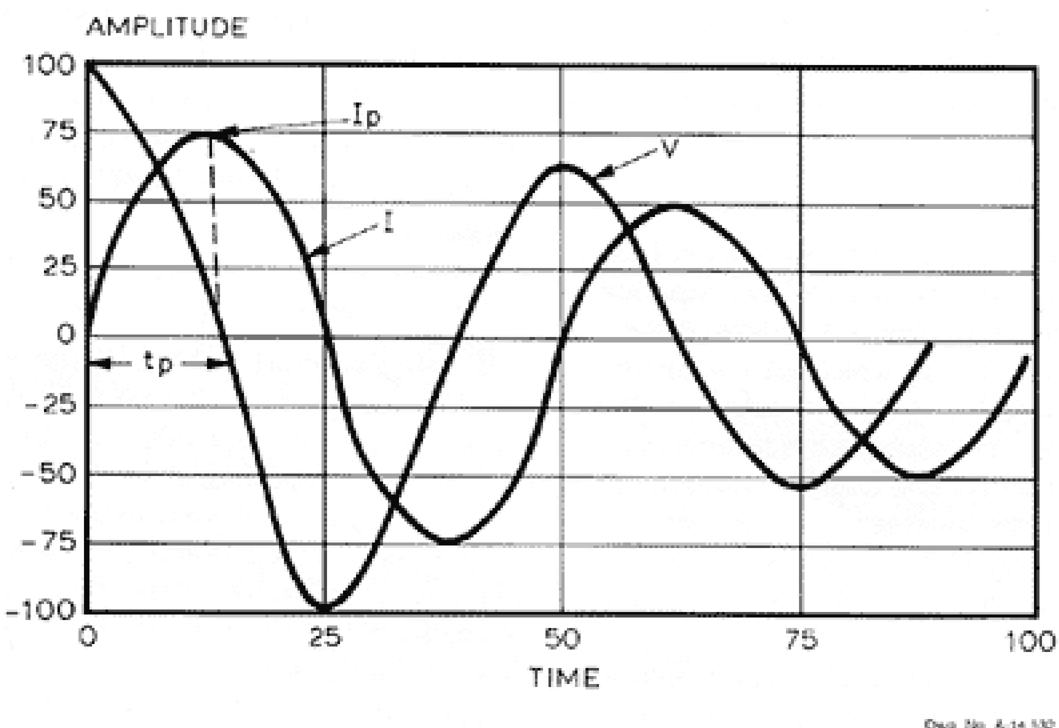


FIGURE #6
OSCILLATORY DISCHARGE WAVE

Oscillating Pulses

The current in amperes of an oscillatory discharge can be obtained using Equation 3, where V is the peak DC charge level in volts, L is the total inductance of the discharge circuit in henries, C is the capacitance value in farads, R is the total equivalent series resistance of the discharge circuit in ohms, t is time to peak current in seconds, $N = \sqrt{1/LC - R^2/4L^2}$, and m= R/2L.

Equation 3

$$I_{RMS} = \frac{V}{LN} \exp(-mt) \sin Nt$$

The magnitude of the first current peak in amperes is given by Equation 4, and the time in seconds to the first current peak can be obtained using Equation 5.

Equation 4

$$Ip = \sqrt{\frac{C}{L}} \exp(-Rt_p/2L)$$

Equation 5

$$tp = \frac{1}{N} \tan^{-1}\left(\frac{N}{M}\right)$$

The first current peak will not occur precisely at the first quarter period of the discharge cycle but at a time slightly before. This is the phase angle at which the peak current occurs and is described by the term tan 1 (N/M) in Equation 5. As the ratio of R/L increases the time to the first current peak decreases.

The current frequency in cycles per second at discharge can be obtained by using Equation 6

Equation 6

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Equation 7

$$\% V_t - 100\exp(-R/4LF)$$

The application conditions of charge voltage, discharge frequency, voltage reversal and duty cycle, all directly impact energy storage capacitor life.

The life of an energy discharge capacitor is expressed in the number of charge/discharge cycles which can e performed before failure. A failure is generally considered as a drop below the required energy transferred (usually loss of capacitance), the inability to store energy until required (usually a severe decrease insulation resistance or a short), or an open circuit (usually end connection failure).

Discharge life may be increased by reducing the changing voltage, or by increasing dielectric thickness appropriately. The cost per joule is increased by voltage derating, and energy density is sacrificed by increasing dielectric thickness. By overrating the capacitor dielectric, the cost per joule is decreased but life is decreased.

Alternate means of increasing the ofe of an energy discharge capacitor are: 1) to minimize voltage reversal, 2) decrease the discharge frequency, and 3) reduce the charge time prior to discharge.

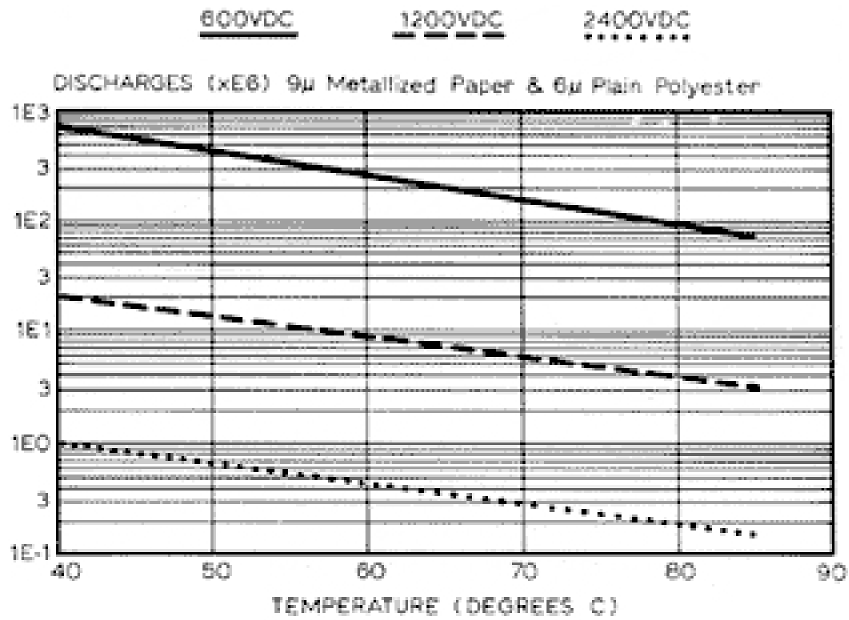
The energy discharge capacitor's life is reduced if the peak discharge current is excessive for the type of end connection and if the duty cycle is increased. Increasing the duty cycle, or repetition rate, reduces life when the temperature rise, due to the resistance of the end connection, and/or the resulting loss inherent to the dielectric system, exceeds the thermal capability of the dielectric.

Graph 3 represents the estimated life as a

When R is very significantly smaller than L, the R2/4L2 term may be disregarded.

Voltage reversal (V) during discharge, which is the ratio between the magnitude of the initial voltage peak and the succeeding voltage peak, can be expressed as a percentage using Equation 7.

function of operating temperature and charge voltage of a wax impregnated energy storage capacitor constructed with 9µ Metallized paper and 6µ Plain polyester.



GRAPH #3
DEVICE LIFE EXPECTANCY

Non-Oscillating Pulses

A non-oscillating discharge pulse occurs when the $R^2/4L^2$ factor in Equation 6 is equal to or greater than 1/LC. Non-oscillatory discharge pulses fall into categories, critically damped and overdamped. Representations of these two forms of discharge pulses are given in Figures 7 and 8.

A wave is critically damped when the discharge circuit satisfies Equation 8.

Equation 8

$$R = 2\sqrt{L/C}$$

the peak discharge current, the time to peak current, and the discharge current at an instant in time of a critically damped discharge can be calculated using Equations 9, 10, and 11 respectively.

Equation 9

$$Ip = 0.368\ V\sqrt{C/L}$$

Equation 10

$$tp=2L/R$$

Equation 11

$$I_T = \frac{V}{L} t \exp\left(-Rt/2L\right)$$

A discharge pulse is overdamped when R is greater than the $2\sqrt{L/C}$ term in Equation 8. The peak current of an overdamped discharge can be calculated using Equation 12.

Equation 12

$$Ip = V\sqrt{\frac{C}{L}} \exp - (R/2L)\ tp$$

The to which is the time to peak current of the overdamped pulse, is defined by Equation 13.

ENERGY DISCHARGE CAPACITOR EVALUATION

When conventional steady state DC capacitors are evaluated, they are usually life tested at specified temperatures and voltages for lengthy durations (eg 250, 2,000 and 10,000 hours). After the test, measurements re typically made of capacitance, dissipation factor and insulation resistance, which are then compared to predetermined minimum or maximum values. The normal criterion used to evaluate energy discharge capacitors is the number of discharges until failure, typified by a short or open condition.

Normally the insulation resistance of the energy discharge capacitor is not used as an electrical end point requirement, since the capacitor is not called upon to store energy for long periods. Experience has shown however, that measurements of insulation resistance and capacitance change can be used to gauge the performance of most energy discharge capacitors especially those designed with metallized dielectrics. When the capacitor under test develops clearings resulting from faults in the dielectric, the electrode area is reduced, decreasing the capacitance. The greater the number of faults, the greater the capacitance change. The insulation resistance of the capacitors will also decrease as the number of clearings increases. By monitoring the dissipation factor, typically at one kilohertz, the integrity of the end connection can be assessed. Some actual individual test results are provided in Table II. The capacitors were tested at +25 degrees ºC, discharging into a load of one ohm at a duty cycle of one discharge every ten seconds at 110% of the rated DC voltage with no voltage reversal.

In most cases there is a minor decrease in

Equation 13

$$tp = \frac{1}{n} \tanh^{-1}\left(\frac{n}{R/2L}\right)$$

$$\text{where } n = \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

One of the simplest ways to minimize inductance is to configure the capacitor package with vertical, parallel terminals. The inductance is consequently reduced by cancellation of opposing fields.

capacitance, a small increase in dissipation factor, and an increase in insulation resistance. This indicates that low insulation resistance areas in the dielectric cleared and that the design is not overstressed. Unit number one is an example of a marginal energy discharge capacitor compared to the similar units two and three. Note that it experienced the largest capacitance change and a significant drop in insulation resistance in a smaller number of cycles performed. By plotting the product of capacitance and insulation resistance versus the number of discharges, performance can be evaluated. Graph 4 provides a life test comparison when energy discharge capacitors similar to those in Table II were tested at: rated voltage at +25 degrees ºC, 140% of rated voltage at +25 degrees ºC and at rated voltage at +85 degrees ºC.

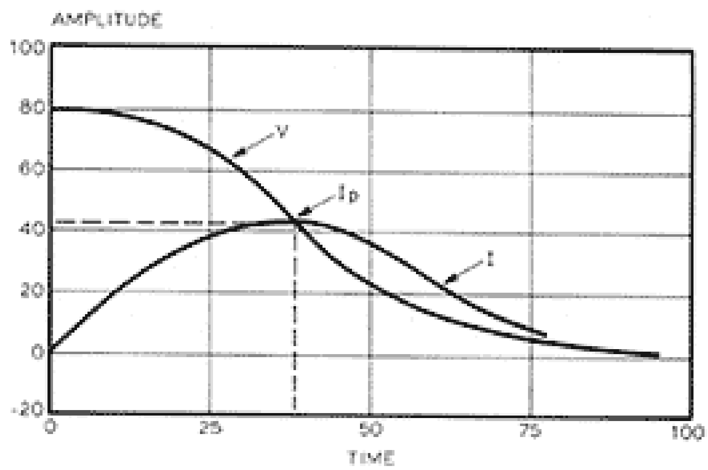


FIGURE #7
CRITICALLY DAMPED DISCHARGE WAVE

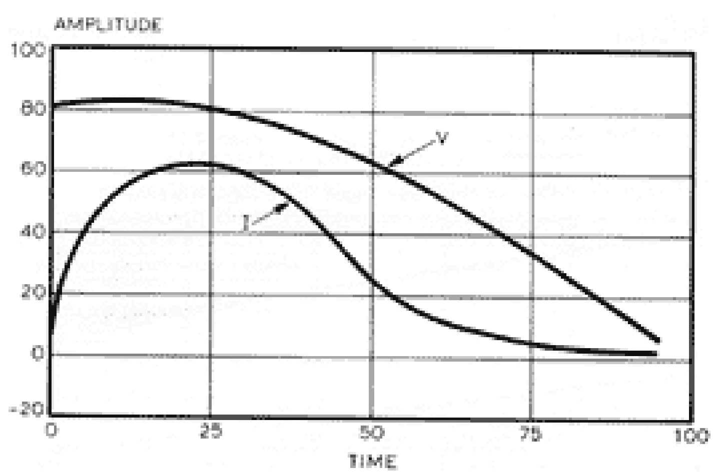
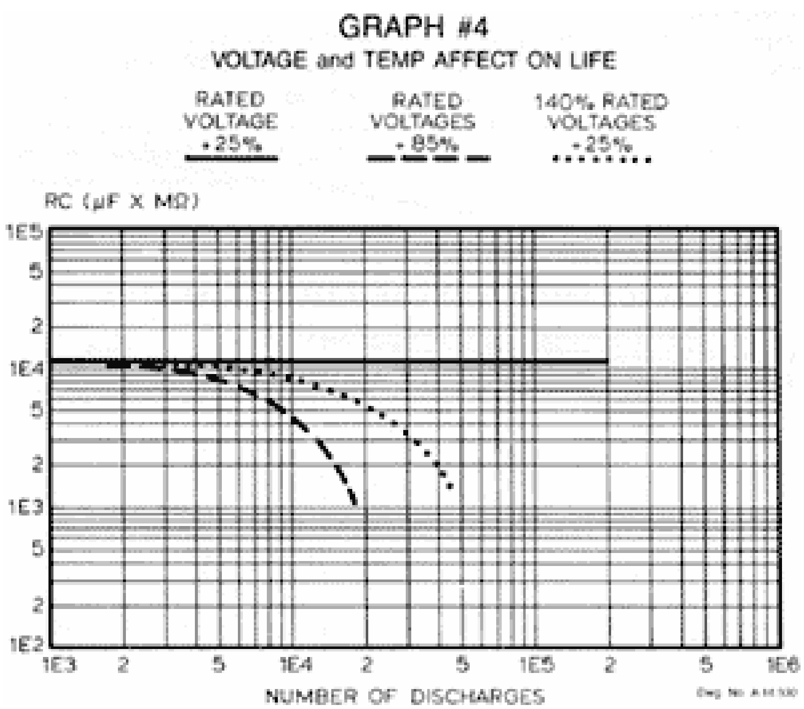


FIGURE #8
OVERDAMPED DISCHARGE WAVE

TABLE II
ENERGY DISCHARGE CAPACITOR EVALUATION

Rating (µF, VDC)	Test Voltage (VDC)	Initial Unit	Initial CAP(µF)	Initial 1KHz D.F.	Initial I.R. (MΩ)	Final CAP(µF)	Final ΔCAP(%)	Final 1KHz D.F.	Final I.R. (MΩ)	Number of Discharges
60 ± 10%, 2500	2750	1	64.0	0.48	510	60.5	-5.5	0.50	160	155,880
		2	64.2	0.52	510	64.2	0	0.35	900	263,000
		3	64.5	0.45	460	64.0	-0.7	0.40	1000	271,000
14 ± 10%, 2000	2200	4	13.7	0.35	2200	13.6	-0.7	0.30	3700	285,000
		5	13.7	0.20	1410	13.6	-0.7	0.30	5000	265,000
		6	13.7	0.28	1470	13.6	-0.7	0.30	6000	285,000
		7	13.7	0.28	1970	13.6	-0.7	0.30	4600	285,000
		8	13.6	0.38	1400	13.6	0	0.40	3700	285,000
115 ± 20%, 2500	2750	9	117.0	0.35	118	116.0	-0.9	0.40	300	300,000
		10	133.0	0.35	170	131.0	-1.5	0.52	200	300,000
		11	124.0	0.32	305	124.0	0	0.38	230	300,000



ACTUAL ENERGY DISCHARGE CAPACITORS AND APPLICATIONS

The Sprague Electric company Film Capacitor Division locate din Longwood, Florida routinely manufactures three basic family types of energy discharge capacitors, which normally are operated from zero to forty degrees centigrade. They are the 28P, 382P, and 681P. a brief comparison of each family is provided in table III and some typical configurations are provided in Photographs 1, 2, and 3.

The 282P was developed by Sprague for laser pumping, uses in satellites, missiles, and other applications which require small, light weight, high energy density packages. They are designed using a multi-layer metallized paper and plain polyester, mineral wax impregnated dielectric system for discharging into xenon flash tubes or similar loads at low repetition rates. They are furnished in drawn-ternplate seamless and welded steel rectangular cases.

The 382P was developed for portable defibrillator systems, but also finds application in beacon strobe light and office copier systems, as well as other applications. Their design consists of a multi-layer metallized paper and plain polyester, silicone oil impregnated dielectric system and are available in cylindrical metal cases with molded plastic covers with threaded insert terminals.

High energy density and light weight are features of the 681P energy discharge capacitors. These capacitors are used in laser, photoflash and aerospace applications. Their design employs the Sprague proprietary composition dielectric with silicone oil impregnation. Type 681P capacitors are available in hermetically sealed cylindrical cases with a single ceramic pillar terminal (case grounded), or with two ceramic pillar terminals (case insulated). Non-hermetic, nonimpregnated, epoxy end filled and tape wrapped designs with axial lead wire configurations are also available.

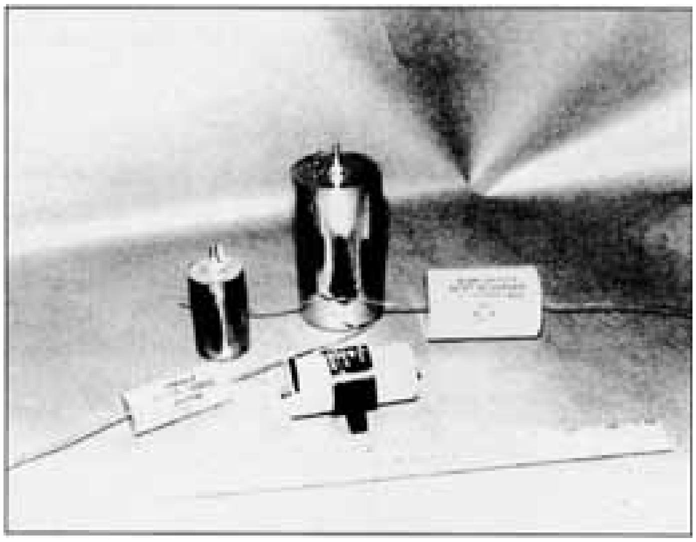
TABLE III
SPRAGUE ELECTRIC ENERGY DISCHARGE CAPACITORS

Family Type	Available Energy (Joules)		Duty Cycle*	Typical* Discharge Life	Peak Discharge* Current	Maximum DC Voltage rating	Capacitance* Ratings (µF)	Typical Series Resistance (Ohms)	Typical Inductance (µH)
	Per In^3	Per lb.							
282P	3	50	1pps	1,500,000	3000	4000	50-200	0.02	0.1
382P	8	140	20ppm	25,000	1000	5800	22-54	0.02	0.1
681P	5	80	10pps	500,000	1500	2500	10-100	0.02	0.005

* Based on existing bulletin designs, with special design considerations by our Design Engineers, higher values are attainable.

PHOTOGRAPH 1: 282P CAPACITORS

PHOTOGRAPH 2: 382P CAPACITORS



PHOTOGRAPH 3: 681P CAPACITORS

PHOTOGRAPH 4: SIZE COMPARISON OF 682P AND 382P CAPACITORS

TABLE V
682P DISCHARGE PERFORMANCE @ +25°C
Rating: 54.0µF, 4000 VDC

Initial		After 5,000 Charge/Discharge Cycles		
1KHz DF (%)	I.R. (MΩ - µF)	ΔCap (%)	1KHz DF (%)	I.R. (MΩ - µF)
1.4	6,000	+1.0	1.4	10,000

The New Type 682P

Recently, Sprague Electric has been developing a new energy discharge capacitor family type for intermittent duty, the 682P. This energy discharge capacitor takes advantage of the high dielectric constant of polyvinylidence difluroide and the silicone oil impregnated soggy-foil design to produce an extremely high energy density capacitor, which is finding application in portable laser range finders, portable medical equipment and as an energy source in ballistic missiles. Table IV provides a size comparison of 54.0?F energy discharge capacitor rated at 4000VDC of the 382P and 682P constructions. A more graphic comparison of the dramatic size reduction realized by the 682P design is provided in Photograph 4.

While the ultimate peak current, duty cycle and life of this capacitor design has yet to be determined, some data is available for review. One group of capacitors has been tested for 5000 charge/discharge cycles at 25 degrees C with 4000 VDC applied. The peak discharge current was 60 amperes at a duty cycle of one pulse per second for six seconds followed by a fifteen minute rest period. Table V provides the mean capacitance, dissipation factor and insulation resistance initially and at the completion of 5,000 cycles. Graph 5 provides the RC product initially and as the test progresses.

Communication = Success

When describing the application and specifying the design criteria for energy discharge capacitors, the user should have some important parameters established. They are:

1. **Operating duty Cycle and Rep Rate.** The maximum repetition rate should be specified, and whether the capacitor will be used intermittently or continuously.
3. **Voltage and Current Requirements.** These parameters let the designer select, based on knowledge and experience, the dielectric system and end connection type best suited for the application.
4. **Life Expectancy** How many charge/discharge cycles are required?
5. **Mechanical Requirements.** The vibration and shock requirements should be specified, since severe stresses may require special internal construction. The size and mounting requirements should be specified with the necessary dimensions and tolerances. Marketing requirements are important as well.
6. **Environmental Conditions.** The environment the device will be subjected to is critical in design work. Is heremeticity required? Will the device be subjected to any corrosive conditions?

When the user has a general understanding of the capabilities and limitations of the energy discharge capacitor (hopefully supplied by these discussions), and clearly describes the application, he and the capacitor Design Engineer can work more effectively together toward the optimum design and use of these special capacitors types.

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2. **Operating Temperature Range.**
Since degradation due to thermal aging is one of the major causes of capacitor dielectric deterioration, the temperature for both non-operating and operating conditions should be specified. It is simplest to specify the minimum and maximum case temperatures at which the capacitor shall operate, since the user may be employing heat sinks, forced air cooling, or liquid transfermedia, etc.

responsible for the diagrams.

References

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2. Final Report, N. Agostinelli, United States Army Electronic Command, Fort Monmouth, New Jersey, July 1970.
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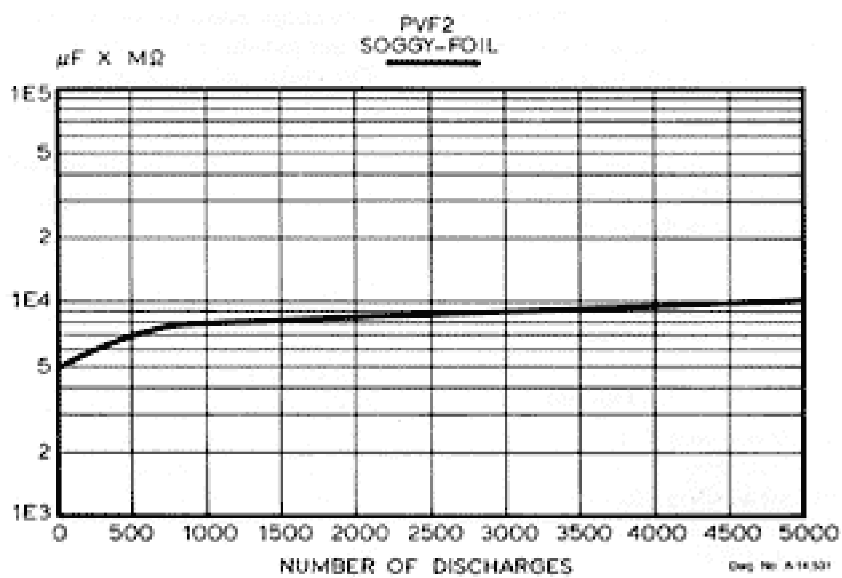
TABLE IV
SIZE COMPARISON OF 682P AND 382P

Parameter	Rating (µF, VDC)	682P	382P
DIAMETER (in.)	54.0, 4000	3.0	3.5
LENGTH (in.)		5.1	6.7
WEIGHT (lb.)		1.7	3.5
Joules/lb		230.4	132.9
Joules/in^3		11.9	6.7



GRAPH #5
682P LIFE