Life Testing of the Power Ring Film Capacitor™ for Automotive DC Link Applications

SBE Inc. is a leading developer and manufacturer of film capacitor solutions that provide a much higher degree of reliability, higher power density, and simpler cooling infrastructure in demanding applications, particularly for automotive/transportation, alternative energy, utilities, power supplies/ laser and military/aerospace. Originally a Sprague Electric Plant, SBE has been manufacturing capacitors for over 50 years; producing over a billion capacitors, including the renowned Orange Drop™. With the newer development of its Power Ring Film Capacitor™, SBE Inc. was awarded a $9.1 Million grant by the Department of Energy to build a world class facility for the manufacture of this line of capacitors used in drivetrain inverters for plug-in hybrid and electric drive vehicles. The company's headquarters, engineering, product development center and manufacturing operation are located in Barre, Vermont.

Overview

Reliability of components is of paramount importance for the automotive industry. While conventional film capacitor products have been evaluated for life expectancy subject to voltage and temperature stress, existing de-rating criteria cannot necessarily be extrapolated to next generation film capacitor designs. Relatively recent advances in high-crystallinity and low-defect polypropylene film can be combined with optimized capacitor form factors to safely support higher ratings. SBE has undertaken an extensive life testing program to demonstrate reliability of the Power Ring annular form factor polypropylene film capacitor. This product offers a unique combination of high capacitance, low ESR, low ESL, and the minimum possible hotspot temperature rise per a given capacitance and ripple current. Results to date have demonstrated a mean time to failure (MTTF) exceeding 20,000 hours subject to realistic conditions using polypropylene film at coolant temperatures up to 105°C.

Oven	Number of Units	DC Voltage	Temperature
1	224	350	107°C
2	224	400	107°C
3	224	450	100°C

Table 1: Voltage and temperature life test matrix.

Test Description

A total of 672 capacitors having a nominal value of 1000 μF were fabricated for life testing, which corresponds to over 1200 lbs of polypropylene film with a stressed area exceeding 70,000 m^2. The parts were split into three equal groups of 224 specimens that were rack mounted for testing as shown in Figure 1. Each group was installed in a dedicated temperature chamber with external wiring to facilitate energizing the capacitors in parallel to a specified DC voltage. Every capacitor was connected to an external indicator lamp set to illuminate if the leakage current exceeded a threshold level corresponding to dielectric failure. The voltage and temperature matrix for the life testing is presented in Table 1.

The life test was run to accumulate over two million unit hours across the three sample populations. Respective run times of 3485 hours, 3193 hours, and 2630 hours were completed for Oven 1, Oven 2 and Oven 3, respectively. At this point the tests for the Oven 1 and Oven 2 conditions were terminated and the capacitors recycled for testing to failure. These parts were run in groups of 10 samples subject to increased levels of combined voltage and temperature stress. The Oven 3 test was resumed and has accumulated over 4784 hours to date, with the ultimate objective of continuing in search of wear out.

Life Test Results

The life data and testing to failure results are summarized in Figure 2, which compares the "safe" operating region with the combined voltage and temperature conditions that precipitate short term failure. Within the defined safe zone, MTTF exceeding 20,000 hours has been demonstrated for all three life test conditions based on a Chi-Squared distribution with 90% confidence. These results become even more powerful when combined with SBE's advanced capacitor simulation tools, which can accurately predict the winding hotspot temperature given customer operating parameters. Further validation is undertaken through in-house temperature rise testing subject to realistic ripple currents and thermal boundary conditions. Contact our application engineering group for further information.

Figure 1: A population of 224 Power Ring capacitors installed on a support rack prior to loading into the thermal chamber.

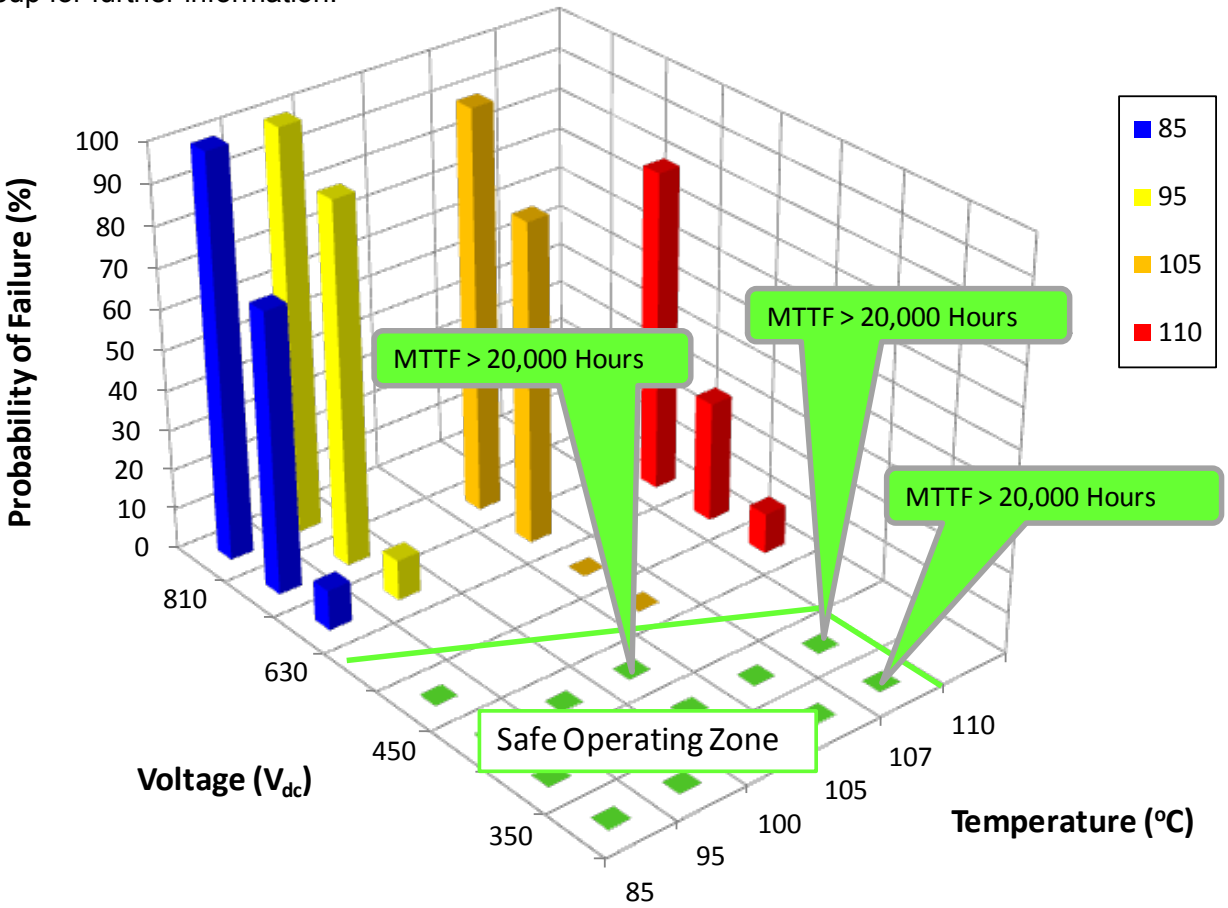

Figure 2: Safe operating conditions for the SBE Power Ring Film Capacitor subject to combined voltage and temperature stress.

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