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ELECTROLYTE FOR ALUMINIUM ELECTROLYTIC CAPACITOR

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ABSTRACT

A suitable electrolyte has been formulated for aluminium electrolytic capacitor and its performance was studied over a temperature range of $-25°C$ to $+85°C$. The climatic, electrical characterisitics and the life endurance test of the capacitor using the developed electrolyte were tested according to ISI specification and the results are discussed.

Key words: Aluminium electrolytic capacitor, glycol based electrolyte

INTRODUCTION

All electronic equipments need at least a few electrolytic capacitors. For the fabrication of electrolytic capacitor, formed anode and etched cathode foil of required size are tagged with leads and wound into a unit by using capacitor paper in between them. The wound unit is required to be impregnated with a film forming electrolyte called working/impregnating electrolyte, to produce flawless capacitor.

The impregnating electrolyte should have the following properties: (i) capable of forming a barrier oxide film (ii) sufficient conductivity to reduce power losses (iii) low water content to prevent deterioration of the anodic film as it reacts with Al especially above $+70°C$ (iv) a resistivity at the operating range of temperature that changes not more than 40 times the resistivity of the electrolyte at room temperature and (v) a pH value between 5.0 and 6.5 to prevent the attack of the electrochemically formed oxide film.

The electrolyte essentially consists of an ionogen capable of forming oxide film preferably borate, formate, citrate neutralised or partially neutralised with ammonia or an amine dissolved in a suitable solvent such as glycol, amides or N-substituted amides and adding phosphate or phosphite or both to reduce the leakage current of the capacitor.

Glycol based electrolytes become highly viscous at low temperature. Moreover the electrolyte is unstable and undergoes reaction during the life of the capacitor. Above $70°C$, water in the electrolyte reacts with the dielectric oxide film leading to poor performance of the capacitor. Amide or N-substituted amide based electrolyte attacks the materials used for the fabrication of capacitor and needs special washers made out of Teflon and neoprene rubber which are relatively costly.

To obviate these disadvantages attempt was made to develop a glycol based electrolyte which can have improved performance in the temperature range of $-25°C$ to $+85°C$ and these studies are reported in this paper. The special electrolyte had the following composition:

Ethylene glycol	50 g by wt
Diethanolamine	20 g by wt
Butyric acid	10 g by wt
Methanol	10 g by wt
Sodium di-hydrogen phosphate	0.4 g by wt

20 g of diethonalamine and 10 g of butyric acid were heated to $55°C - 60°C$ for 5 min. followed by addition of 50 g of ethylene glycol and the mixture was heated to $105°C$ and maintained at that temperature for 10 min. to expel water. 0.4 g of sodium dihydrogen phosphate was added. After cooling the mixture to room temperature, 10 g of methanol was added.

The resistance of the electrolyte was measured at $25°C$ using conductivity bridge. The resistance was 200 ohms. The electrolyte was then kept inside the Thermostat. The resistance of the electrolyte was measured maintaining the desired temperature for 15 min. The resistance of the electrolyte at $-30°C$ was 7550 ohm. To study the performance characteristics, climatic tests and endurance test was carried out after fabricating capacitor of rating 25 V, 50 MFD impregnated with the electrolyte as per IS: Specification 4317 – 1967. Five capacitors were studied for each test.

Before starting the test, the components were charged to the rated voltage for 10 min. and at the end of this period, the leakage current, power factor and the capacitance were measured at a frequency of 50 Hz using a capacitance bridge applying an a.c. voltage but not exceeding 0.5 volts r.m.s.

Table I gives the capacitance, power factor and leakage current at $+25°C$ According to the specification, the CV product greater than 1000, the leakage current shall not exceed $0.03\,CV + 20\,\mu A$ which is equivalent to $57.5\,\mu A$. the tolerance of the rate capacitance value shall not exceed -20 to $+100\%$ and the tangent of the loss angle at frequency 50 Hz not to exceed 35. From the data in the Table, one finds that the maximum change in capacitance value is $+25\%$ and power factor 0.15 and leakage current at the maximum $7\,\mu A$. The values are well within the specification.

Table I: Performance at low temperature

	1	2	3	4	5
Initial reading at room temperature (25° C)					
Capacity (μF)	60	58	54	62	50
Power factor	0.085	0.085	0.150	0.095	0.115
Leakage current (μA)	4.5	7.0	3.5	3.5	2.5
At low temperature of – 30° C					
Capacity (μF)	49	45	44	52	38
Power factor	0.30	0.43	0.37	0.32	0.29
Leakage current (μA)	1.0	1.5	Nil	1.0	Nil
Final reading at room temperature (25° C)					
Capacity (μF)	58	59	54	63	48
Power factor	0.080	0.085	0.110	0.095	0.100
Leakage current (μA)	3	2	2	4	3

DRY HEAT TEST

This test was carried out to determine whether the electrolyte system is suitable for high temperature operation. The components tested at + 25°C were mounted on an insulating board capable of withstanding + 85°C and was placed in a hot chamber, the temperature of which was maintained by a control with a tolerance of ± 1°C and direct heat radiation from the heating elements to the capacitors was avoided.

The capacitors were kept at that temperature for 16 hrs applying the rated voltage. At the end of the period while still at + 85°C, the capacitance, power factor and leakage current were measured and tabulated in Table II. The leakage current according to the specification should not exceed 4 times the initial value (285 μA). After the conclusion of the test, the capacitance was only 13 μF which is well within the specification and no seepage of the electrolyte and any sign of corrosion of the container occurred.

Table II: Performance at high temperature

	1	2	3	4	5
Initial reading at − 25° C					
Capacity (μF)	48	58	56	54	54
Power factor	0.055	0.080	0.065	0.075	0.070
Leakage current (μA)	1	2	2	2	3
At 85° C					
Capacity (μF)	48	51	52	48	52
Power factor	0.065	0.100	0.095	0.085	0.090
Leakage current (μA)	13	3	2	1	1

COLD TEST

At the end of the test, the components were removed from the chamber and allowed to remain under atmospheric conditions for recovery, for a period of 1-2 hrs. The capacitors were immediately subjected to cold test in the thermostat which is capable of maintaining − 30°C with a tolerance of ± 2°C. The temperature was maintained at − 25°C for two hours and the capacitors were kept under load during this exposure. At the end of the period the components were measured while still at − 25°C for capacitance, power factor and leakage current values. The ratio of impedance at low temperature (− 25°C) to the room temperature was calculated which should not exceed by a factor of 2. The components were removed from the chamber and allowed to remain under normal atmospheric condition for recovery for 1 1/2 hrs and the water droplets on the container were wiped and again kept for not less than one hour or more than two hours. The capacitance was measured after recovery from cold cycle which should not exceed 5% of the initial value.

From the values given in Table I, the change in the ratio of impedance calculated is not more than 1.4 times of the limit specified and the change in capacitance was within 4% of the previously measured value without any seepage of the electrolyte and no damage was observed on visual inspection.

ENDURANCE TEST

Another batch of five capacitors were mounted on an insulting board and the values of capacitance, power factor and leakage current were measured. In order to provide free ventilation, the capacitors were placed in the test chamber in such a manner that no capacitor is within 25 mm of any other capacitor. The temperature of the test chamber was kept at + 85°C such that the ambient temperature of the capacitor under no circumstances exceeds the upper category temperature. All the capacitors were protected from the direct heat from the heating elements and circulation of air was provided within the chamber so that the temperature difference in any part of the chamber does not exceed ± 3°C. During the entire conditioning period, the capacitors were subjected to an a.c. voltage of approximately sinusoidal wave form at a frequency of 50 to 60 c/s superimposed on a d.c voltage such that the rated ripple current was applied to the capacitor and the peak voltage equalled the rated voltage.

At the end of the test period of 1000 hrs, the capacitors were allowed to remain under standard recovery period of 16 hrs. The capacitance was visually examined for seepage of the electrolyte or other visual damage. According to the specification, leakage current should not exceed 57.5 μA and the capacitance change must be within 15% of the previously measured value and the power factor 1.3 times the limited value of 0.35 and ratio of impedance change after the endurance test to the initial value should not exceed 2 times. From the test values tabulated in Table III, the capacitance value changes only 12% and leakage current at the maximum 10 μA as against 57.5 μA with the impedance change of 1.13 times only.

Table III: Endurance test

Six capacitors were subjected to 1000 hrs. life test at the rated temp. of 85°C. The rated voltage of 25 V D.C. was applied throughout the life test.

Sl. No. of capaci-tors	Initial value before starting the experiment			After 1000 hrs. at 85°C and maintaining for another 16 hrs. at 25°C		
	Capacity (μF)	Power factor	Leakage current (μA)	Capacity	Power factor	Leakage current (μA)
1	48	0.055	1	47	0.080	10
2	54	0.070	3	51	0.105	3
3	58	0.080	2	52	0.090	3
4	54	0.075	4	48	0.170	2
5	56	0.065	2	50	0.080	1
6	54	0.075	2	53	0.090	2

CONCLUSION

From the above three important tests, it can be inferred that the electrolyte developed gives satisfactory performance for general purpose application of aluminium electrolytic capacitor over the temperature range between − 25°C and + 85°C.