

EESTOR INC.

TEST REPORT

SCOPE OF WORK

Performance testing of capacitive samples (Ceramic samples called 105-7, 207-2, 344-2B)

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TEST REPORT

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Cedar Park, TX 78613 – USA
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Subject: Performance testing of capacitive samples (Ceramic samples called 105-7, 207-2, 344-2B)

Dear Bryan Kelly,

This letter report represents the results of our evaluation of the above referenced samples.

SECTION 1 SUMMARY

Four unique samples were tested at the EESTOR Inc. facility at 715 Discovery Blvd. Ste: 107, Cedar Park, Texas, 78613, USA on the 4th of Jan 2018. There, samples were identified as 105-7, 207-2, 344-2B. Samples were subjected to the measurements and calculation outlined in section 2 of this report.

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SECTION 2
TESTING AND CALCULATION

The items below represent a summary of the tests and results.

Test Location: 715 Discovery Blvd. Ste:107, Cedar Park, Texas 78613

Test Date: 4-JAN-2018

Test Site Ambient Conditions: 20.7°C, 15.6%RH

Equipment List:

Equipment Asset Number	Equipment Type	Manufacturer Name	Model Number	Calibration Date	Calibration Due Date
(Intertek) 260	Temperature / Humidity Monitor	Extech	445580	9/20/2017	9/20/2018
(Intertek) 1479	LCR Meter	BK Precision	878B	5/14/2017	5/14/2018
(Intertek) 1191	Micro meter	Accuremote	0-1"	10/23/2017	10/23/2018
(EESTOR)	IR Meter	VITREK	957i	12/15/2017	12/15/2018

Below formula used to calculate some of the parameters.

Formula used to find relative permittivity of the dielectric material (k):

- 1) $k = dC / \epsilon_0 A$
Where:
d = Sample thickness (m)
C = Measured capacitance (F)
 ϵ_0 = Permittivity of space (8.854×10^{-12} F/m)
A = Area of circular plate based on measured diameter (m²)

Formula used to find Energy Density of the sample (in Wh/L):

- 1) Energy W in Joule = $1/2 CV^2$
Where
C = Measured capacitance (F)
V = Measured peak voltage (V)
- 2) Volume in cm³ / m³ = Area x Thickness x 1,000,000
Where
Area of electrode = Calculated in m²
Thickness of electrode = Calculated in meter
- 3) Energy density in (Wh/L) = (Energy in Joule/3600) / (Volume in cm³/m³/1000)

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Parameters measurement and calculation:

VAC Parameters at 1 V and 1 kHz						
Measured						Calculated
Voltage (V rms):		1				
Frequency (kHz):		1				
Sample ID	Electrode shape	Electrode width (mm)	Dielectric thickness (μm)	Dissipation Factor DF	Capacitance C (nF)	Relative permittivity k
105-7	Round	6.09	464	0.010	1.29	2321
207-2	Round	6.09	488	0.018	0.84	1589
344-2B	Round	2.94	32	0.0460	0.89	474

VAC Parameters at 300 V and 60 Hz							
Measured						Calculated	
Voltage (V rms):		300					
Frequency (Hz):		60					
Sample ID	Electrode shape	Electrode width (mm)	Dielectric thickness (μm)	Dissipation Factor DF	Capacitance C (nF)	Relative permittivity k	Electric Field (Vrms/μm)
344-2B	Round	2.94	32	0.0930	0.86	458	9.375

VAC Parameters at 500 V and 60 Hz							
Measured						Calculated	
Voltage (V rms):		500					
Frequency (Hz):		60					
Sample ID	Electrode shape	Electrode width (mm)	Dielectric thickness (μm)	Dissipation Factor DF	Capacitance C (nF)	Relative permittivity k	Electric Field (Vrms/μm)
105-7	Round	6.09	464	0.033	1.37	2465	1.078
207-2	Round	6.09	488	0.098	1.25	2365	1.025

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VDC Parameters for Sample ID: 105-7							
Measured			Calculated				
Electrode Shape:		Round					
Electrode width (mm):		6.09					
Dielectric thickness (μm):		464					
Voltage DC (V)	Capacitance C (nF)	Leakage current (nA)	Resistance iR (GΩ)	Relative permittivity k	Electric Field (V/μm)	Energy Density (Wh/l)	Time Constant (s)
500	1.47	0.3	1667	2645	1.1	0.00	2450
1000	1.24	0.6	1667	2231	2.2	0.01	2067
1500	1.02	1.0	1500	1835	3.2	0.02	1530
2000	0.90	1.0	2000	1619	4.3	0.04	1800
3000	0.71	1.8	1667	1277	6.5	0.07	1183
4000	0.58	2.3	1739	1043	8.6	0.10	1009
5000	0.516	2.9	1724	928	10.8	0.13	890
6000	0.44	3.1	1935	792	12.9	0.16	852
7000	0.39	3.1	2258	702	15.1	0.20	881
8000	0.36	3.7	2162	648	17.2	0.24	778
9000	0.32	4.2	2143	576	19.4	0.27	686
10000	0.30	4.8	2083	540	21.6	0.31	625
10500	0.29	4.9	2143	522	22.6	0.33	621
11000	0.28	4.8	2292	504	23.7	0.35	642
11500	0.28	4.9	2347	504	24.8	0.38	657
12000	0.26	5.1	2353	468	25.9	0.38	612
12500	0.26	5.6	2232	468	26.9	0.42	580

VDC Parameters for Sample ID: 207-2							
Measured			Calculated				
Electrode Shape:		Round					
Electrode width (mm):		6.09					
Dielectric thickness (μm):		488					
Voltage DC (V)	Capacitance C (nF)	Leakage current (nA)	Resistance iR (GΩ)	Relative permittivity k	Electric Field (V/μm)	Energy Density (Wh/l)	Time Constant (s)
500	1.21	0.3	1667	2289	1.0	0.00	2017
1500	0.96	0.8	1875	1816	3.1	0.02	1800
3000	0.66	0.6	5000	1249	6.1	0.06	3300
3500	0.61	0.9	3889	1154	7.2	0.07	2372

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VDC Parameters for Sample ID: 207-2 continue from page 5...							
Measured			Calculated				
Electrode Shape:	Round						
Electrode width (mm):	6.09						
Dielectric thickness (μm):	488						
4500	0.51	1.8	2500	965	9.2	0.10	1275
5500	0.44	2.2	2500	833	11.3	0.13	1100
6500	0.39	3.2	2031	738	13.3	0.16	792
7500	0.36	4.6	1630	681	15.4	0.20	587
8500	0.32	6.3	1349	605	17.4	0.23	432
9500	0.30	8.6	1105	568	19.5	0.26	331
10500	0.28	12.1	868	530	21.5	0.30	243
11000	0.27	12.5	880	511	22.5	0.32	238
11500	0.26	14.4	799	492	23.6	0.34	208
12000	0.25	17.1	702	473	24.6	0.35	175
12500	0.24	20.7	604	454	25.6	0.37	145
13000	0.23	25.5	510	435	26.6	0.38	117
13500	0.23	31.6	427	435	27.7	0.41	98
14000	0.22	37.6	372	416	28.7	0.42	82
14500	0.21	47.9	303	397	29.7	0.43	64

VDC Parameters for Sample ID: 344-2B							
Measured			Calculated				
Electrode Shape:	Round						
Electrode width (mm):	2.94						
Dielectric thickness (μm):	32						
Voltage DC (V)	Capacitance C (nF)	Leakage current (nA)	Resistance iR (GΩ)	Relative permittivity k	Electric Field (V/μm)	Energy Density (Wh/l)	Time Constant (s)
300	1.21	0.4	750	644	9.4	0.07	908
500	0.90	0.5	1000	479	15.6	0.14	900
750	0.74	0.4	1875	394	23.4	0.27	1388
1000	0.61	0.7	1429	325	31.3	0.39	871
1250	0.53	0.8	1563	282	39.1	0.53	828
1500	0.46	0.8	1875	245	46.9	0.66	863
1750	0.41	0.8	2188	218	54.7	0.80	897
2000	0.37	1	2000	197	62.5	0.95	740
2250	0.34	1.3	1731	181	70.3	1.10	588
2500	0.31	1.5	1667	165	78.1	1.24	517
2750	0.29	1.8	1528	154	85.9	1.40	443

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Breakdown voltage					
Measured					Calculated
Sample ID	Electrode shape	Dielectric thickness (μm)	Highest DC voltage of stable C (V)	Breakdown DC Voltage (V)	Highest Field (V/μm)
105-7	Round	464	12500	13000	28.017
207-2	Round	488	14500	15000	30.738
344-2B	Round	32	2750	3000	93.750

SECTION 3

RESULTS

NA

SECTION 4

PHOTOGRAPHS

No photographs provided per the request of EESTOR Inc.

SECTION 5

PROJECT STATUS & ACTION

Issuance of this letter report completes the testing portion covered by Intertek Project No. G103362995.

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact your dedicated Intertek Project Engineer.

Completed by:	Bhaul Patel (BD)	Reviewed by:	Javier Lozano
Title:	Project Engineer	Title:	Industrial Team Lead
Signature:		Signature:	
Date:	2/26/2018	Date:	2/26/2018