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PROPERTIES OF SPECIALIZED
CLEVITE CERAMICS

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INTRODUCTION

The purpose of this memorandum is to summarize as completely as possible the important properties of PZT-6A1, PZT-6A2, PZT-6B, and PZT-7A. In this respect it may be considered a specialized addendum to Engineering Memorandum No. 64-1, which describes the properties of Ceramic B, PZT-2, PZT-4, PZT-5A, and PZT-5H.

The first section of this memorandum contains a brief discussion of the important characteristics of these materials, with recommendations for particular applications. The following section lists the symbols and units used in the sections to follow.

The third section lists room temperature low signal parameters in s form as nearly complete as possible. Complete sets of elastic, piezoelectric and dielectric constants are listed for PZT-7A and PZT-6B, and partial sets are listed for PZT-6A1 and PZT-6A2. The listed properties are subject to fluctuations from element to element or from batch to batch and the anisotropy ratios (s_{11}/s_{33} , s_{12}/s_{13} , s_{44}/s_{66} , $\epsilon_{11}/\epsilon_{33}$) vary drastically with thoroughness of poling. The values presented here are, however, self consistent and hold for the level of poling suggested by the coupling factors listed. It should be noted that the poling level can be and sometimes is systematically varied with the filter-type materials (PZT-6 family) in order to control bandwidth.

The fourth section gives data relating to temperature and time stability. Data are for samples subjected to appropriate temperature stabilizing treatment. This treatment reduces markedly temperature hysteresis effects and causes a relatively small decrease in piezoelectric coupling and increase in dielectric constant. This treatment is always used with PZT-6 compositions but it is used only when specifically required with other PZT compositions. Aging data are listed as % change per time decade. These changes tend to be linear as function of the log of time, but there are significant deviations from this behaviour.

Section V lists high signal properties. Since these materials are not generally used in situations where these characteristics are important, data listed are very much less complete than in the corresponding section of Engineering Memorandum 64-1.

The curves attached to this report show variation of ϵ_{33}^T , k_p , g_{31} , d_{31} , N_1 and Q_M with temperature for these compositions (after temperature stabilization).

I. GENERAL COMPARISON

PZT-6 compositions are recommended for use in electromechanical filters mostly in the range below 2 MHz. These ceramics have much better stability (time and temperature) than other commercial ceramics. The choice among PZT-6A1, PZT-6A2, and PZT-6B is usually on the basis of filter bandwidth, and for this purpose the coupling factor may be adjusted within limits for each composition. PZT-6B has much lower dielectric constant and much higher mechanical Q over a wide temperature range than PZT-6A1 or PZT-6A2.

PZT-7A is recommended for applications requiring low permittivity, such as high frequency delay lines. It has high sensitivity and good time stability.

II. UNITS AND DESCRIPTION OF SYMBOLS

Units and symbols are identical to those used in Engineering Memorandum 64-1. For convenience units are listed again below:

d= 10^{-12} C/N or 10^{-12} m/V
g= 10^{-3} Vm/n or 10^{-3} m²/C
e= C/m² or N/Vm
h= 10^8 V/m or 10^8 N/C
s= 10^{-12} m²/N
c= 10^{10} N/m²
v= m/second
N= cycle m/second
Density= 10^3 kg/m³

III. TYPICAL ROOM TEMPERATURE DATA (LOW SIGNAL)

	PZT-6A1	PZT-6A2	PZT-6B	PZT-7A
Temperature Stabilized				
$\epsilon_{33}^T/\epsilon_0$	1050	890	460	425
$\epsilon_{33}^S/\epsilon_0$	730	680	386	235
$\epsilon_{11}^T/\epsilon_0$			475	840
$\epsilon_{11}^S/\epsilon_0$			407	460
$\tan \delta$	0.02	0.02	0.009	0.017
k_p	0.42	0.35	0.25	0.51
k_{31}	-0.248	-0.207	-0.145	-0.30
k_{33}	0.54	0.47	0.375	0.66
$k_{15} = k_{11}$			0.377	0.67
k_t	0.39	0.35	0.302	0.50
k_{13}	0.55	0.48	0.40	0.67
d_{31}	-80	-59.5	-27	-60
d_{33}	189	151	71	150
d_{15}			130	362
g_{31}	-8.5	-7.5	-6.85	-15.9
g_{33}	20.4	19.2	18.0	39.9
g_{15}			30.8	48.8
h_{31}			-2.7	-10.2
h_{33}	19.4	17.0	20.7	45.8
h_{15}			12.7	23.0
e_{33}	12.5	10.2	7.1	9.5
e_{31}			-0.92	-2.11
e_{15}			4.6	9.2
s_{11}^E	10.7	11.2	9.0	10.7
s_{33}^E	13.0	13.0	9.35	13.9
s_{44}^E			28.2	39.5
s_{12}^E	-3.2	-3.4	-3.0	-3.2
s_{13}^E			-3.1	-4.6
s_{66}^E	27.8	29.2	24.0	27.8
s_{11}^D	10.1	10.7	8.8	9.7
s_{33}^D	9.2	10.1	8.05	7.85
s_{44}^D			24.2	21.8
s_{12}^D	-3.8	-3.9	-3.2	-4.2
s_{13}^D			-2.6	-2.3
c_{11}^E			16.8	14.8
c_{33}^E	13.1	12.6	16.3	13.1
c_{44}^E			3.54	2.53
c_{66}^E	3.6	3.4	4.17	3.60
c_{12}^E			8.51	7.62
c_{13}^E			8.40	7.42
c_{11}^D			16.9	15.7
c_{33}^D	15.5	14.4	17.7	17.5

	PZT-6A1	PZT-6A2	PZT-6B	PZT-7A
Temperature Stabilized				
c_{44}^D			4.13	4.72
c_{12}^D			8.62	8.54
c_{13}^D			8.24	7.30
Q_M	450	550	1300	600
Q_E	50	50	110	60
N_1	1770	1730	1920	1750
N_{3t}	2140	2090	2225	2100
N_{3a}	1910	1820	2030	2050
v_3^D	4570	4400	4820	4800
v_4^D			2340	2490
v_4^E			2160	1820
Curie Point	335°C	335°C	~350°C	~350°C
ρ	7.45	7.45	7.55	7.6

IV. TEMPERATURE & TIME STABILITY				
	PZT-6A1	PZT-6A2	PZT-6B	PZT-7A
Change in N_1 / Time Decade				
Typical	0.03 to 0.05%	0.07 to 0.1%	0.04 to 0.08%	-0.08%
Advertised Values	<0.1%	<0.1%	<0.1%	
Change in k_p / Time Decade				
Typical	-0.2%	-0.2%	-0.2%	0.0%
Change in e_{33}^T / Time Decade				
Typical	-0.6%	-0.6%	-0.6%	2%
Change in N_1 , -40 to +85°C				
Typical	0.1%	0.1%	0.1%	2.9%
Advertised Values	<0.2%	<0.2%	<0.2%	-
Volume Resistivity in Ωm				
25°C	$>10^9$	$>10^9$	$>10^{10}$	$>10^9$
100°C	10^7	10^7	$10^{8.5}$	10^8
200°C	10^5	10^5	$10^{6.5}$	$10^{6.5}$
Time Constant, seconds				
25°C	>10	>10	>100	>10
100°C	0.15	0.15	1.5	0.5
200°C	0.002	0.002	0.03	0.03
<p>The data on temperature and time stability of N_1 for the PZT-6 composition were obtained from A. Lungo</p> <p>Antiresonant frequencies for PZT-6 discs typically change 0.01 to 0.02% less than the resonant frequencies (A. Lungo)</p>				

V. HIGH SIGNAL PROPERTIES (In this table, units of Electric Field are kV/cm rms)

	PZT-6A1	PZT-6A2	PZT-6B	PZT-7A
AC Depoling Field	8	8	>10	>10
AC Field for $\tan\delta=0.04$, 25°C	3.2	3.2	11	2.6
AC Field for $\tan\delta=0.04$, 100°C	2.8	2.8	5	1.3
P ($\mu\text{C}/\text{cm}^2$)	30	30	15	42
Curie Point	335°C	335°C	~350°C	~350°C
Compressive Strength, psi	>75000	>75000	>75000	>75000
Tensile Strength, static, psi	~11000	~11000	~11000	~11000
Tensile Strength, dynamic, psi	~3500	~3500	~3500	~3500







