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Materials Technical Data (Typical Values)

Property	Symbol	Units	Material Type			
			PZT-5A	PZT-5J	PZT-5H	PMN-PT
Dielectric Constant (1kHz)	K^T_3		1800	2100	3800	4753
Dielectric Loss Factor (1kHz)	$Tan\delta_e$	%	0.02	0.02	2.0	
Dielectric Constant (1kHz)	K^T_1		1600	2948		
Clamped Dielectric Constant	K^S_3		900	800	1200	
Density	ρ	g/cm^3	7.95	7.90	7.87	8120
Curie Point	T_c	°C	350	270	225	
Mechanical Quality Factor	Q_m		80	60	32	150
Coercive Field (Measured < 1Hz)	E_c	kV/cm	12.0	10.0	8.0	5.3
Remanent Polarization	P_r	$\mu Coul/cm^2$	39.0		39.0	
Coupling Coefficients	k_p		0.68	0.72	0.75	
	k_{33}		0.72	0.74	0.75	0.89
	k_{31}		0.35	0.37	0.44	0.46
	k_t		0.49	0.53	0.55	
	k_{15}		0.61	0.77	0.78	
Piezoelectric Charge (Displacement Coefficient)	d_{31}	$Coul/N \times 10^{-12}$ or $m/V \times 10^{-12}$	-190	-270	-320	-646
	d_{33}		390	485	650	1285
	d_{15}		460	850	1000	
Piezoelectric Voltage Coefficient (Voltage Coefficient)	g_{31}	$V \cdot m/N \times 10^{-3}$	-11.3	-10.4	-9.5	-15.4
	g_{33}		23.2	21.3	19.0	30.6
	g_{15}		32.4	32.6	35.3	
Frequency Constants Radial	N_r	kHz · cm		191		
Resonant Thickness	N_{tr}	kHz · cm	211	205	202	
Anti-Resonant Thickness	N_{ta}	kHz · cm	236	235	236	
Thermal Expansion (Perpendicular to Poling)	α	ppm/°C	3.0		3.5	
Specific Heat	C_p	J/kg · °C	440		420	
		J/mol · °C	145		138	
Thermal Conductivity with Au Electrodes	K_d	W/cm · °C	1.9-2.3		1.9-2.3	
		W/m · °K	1.2		1.2	
		W/m · °K	1.45		1.45	
Poisson's Ratio	υ		0.34	0.31	0.31	
Elastic Constants Short Circuit	S^E_{11}	$\times 10^{-12} m^2/N$	15.1	15.8	16.6	
	S^E_{33}		18.6	18.8	21.0	
	S^E_{12}		-4.8	-5.0		
	S^E_{13}		-7.6	-7.7		
	S^E_{55}		40.0	47.0	52.4	
Elastic Constants Open Circuit	S^D_{11}	$\times 10^{-12} m^2/N$	12.7	12.6	13.9	
	S^D_{33}		9.0	8.5	8.8	
	S^D_{55}		25.1	19.1	20.5	
Elastic Constants Short Circuit	Y^E_{11}	$\times 10^{10} N/m^2$	6.6	6.4	6.2	2.2
	Y^E_{33}		5.4	5.3	4.9	2.0
Elastic Constants Open Circuit	Y^D_{11}	$\times 10^{10} N/m^2$	7.9	7.9	7.0	
	Y^D_{33}		11.1	11.7	11.0	

Formulas	
Disc Capacitance	$(d^2 \cdot K^T_3)/(5.67 \cdot t)$
Plate Capacitance	$(l \cdot w \cdot K^T_3)/(4.45 \cdot t)$
Disc K^T_3	$(5.662 \cdot Cap \cdot t)/d^2$
Plate K^T_3	$(4.447 \cdot Cap \cdot t)/(l \cdot w)$
f_r (radial)	$N_r/(2.54 \cdot d)$
f_r (length)	$N_{31r}/(2.54 \cdot l$
f_r (width)	$N_{31r}/(2.54 \cdot w)$
f_t (thickness)	$Nt/(2.54 \cdot t$

Formula length, width, and diameter are for electroded area only.

Definitions					
$tan\delta_e$	Dielectric Loss Factor	C	Capacitance (nF)	N_r	Radial Frequency Constant
ρ	Mass Density of Ceramic	l	Length (in.)	N_t	Thickness Mode Frequency Constant
T_c	Curie Point	W	Width (in.)	P_r	Remanent Polarization
d_{33}	Direct Charge Coefficient	d	Diameter (in.)	Q_m	Mechanical Q (Quality Factor)
d_{31}	Transverse Charge Coefficient	t	Thickness (10^{-3} in.)	Y^E_{33}	Direct Young's Modulus
E_c	Coercive Field	k_{33}	Direct Electromechanical Coupling Coefficient	Y^E_{11}	Elastic Modulus
g_{33}	Direct Voltage Coefficient	k_{31}	Transverse Electromechanical Coupling Coefficient	f_r	Resonant Frequency
g_{31}	Transverse Voltage Coefficient	K_{T3}	Free Dielectric Constant Measured Along Poling Axis	f_a	Anti-Resonant Frequency
k_p	Planar Electromechanical Coupling Coefficient				