Devices thru Material Innovation

NEC/TOKIN

Vol.04

Piezoelectric Ceramics

⚠

●All specifications in this catalog and production status of products are subject to change without notice. Prior to the purchase, please contact NEC TOKIN for updated product data.
●Please request for a specification sheet for detailed product data prior to the purchase.
●Before using the product in this catalog, please read "Precautions" and other safety precautions listed in the printed version catalog.

2010.03.19 9307PIEVOL04E

⚠

- All specifications in this catalog and production status of products are subject to change without notice. Prior to the purchase, please contact NEC TOKIN for updated product data.
- Please request for a specification sheet for detailed product data prior to the purchase.
- Before using the product in this catalog, please read "Precautions" and other safety precautions listed in the printed version catalog.

INTRODUCTION

1) A

2)

3)

4)

5) A

References

Please refer to the following bibliography if you want more details of basic theory and applications of transducers:

1) Ultrasonic technology handbook (J. Tomoyoshi et al, Nikkan Kogyo Shinbun)
2) Ceramic dielectrics (K. Okazaki, Gakkensha)
3) Physical Acaustic Vol I Part A (Mason, Academic Bress)
4) Piezoelectric ceramic materials (T.Tanaka, Denpa Shinbun)
5) Piezoelectric ceramics and their applications (Electronic materials Association, Denpa Shinbun)
6) New ultrasonic wave technologies (E. Mori, Nikkan Kogyo Shinbun)
7) Ultrasonic engineering (H. Wada, Nikkan Kogyo Shinbun)
8) Ultrasonic circuit (S. Ishiwata, Nikkan Kogyo)
9) Ultrasonics in medicine (compiled by The Japan Society of Ultrasonics in Medicine, Igaku Shoin)
10) Simple applications of ultrasonics (S. Fujimori, Sanpo)
11) Electromechanical functional parts (compiled by Specialized Committee of The Institute of Electrical Engineers of Japan)
12) Test methods for piezoelectric ceramic transducers (EMAS-6001 to EMAS-6004)
(Piezoelectric Ceramic Engineering Committee, Electronic Materials Association)

Design Materials

Outline

A piezoelectric material responds mechanically when voltage is applied, and conversely, generates a voltage in response to a mechanical change.

To create piezoelectric ceramics, polycrystalline ceramics are fired and baked at a high temperature. Then electrodes are mounted and a DC field applied in order to polarize the ceramic material; once polarized, the material exhibits piezoelectric properties, allowing it to be used as a piezoelectric ceramic transducer. These transducers are also called electrostriction transducers, since ceramic crystals are deformed by electricity.

Barium titanate and lead zircotitanate are the most popular piezoelectric ceramics. In addition, NEC TOKIN also uses a variety of other materials, including conventional lead zircotitanate.

This results in piezoelectric materials that can be used in a wide variety of applications: those that use the piezoelectric effect (such as igniters and pickups), those that utilize resonance (e.g., filters), and those that utilize the electrostrictive effect (such as piezoelectric buzzers and displacement elements).

In addition to barium titanate and lead zircotitanate, popular as piezoelectric ceramics, NEC TOKIN offers multi-component solid ceramics developed from conventional lead zircotitanate ceramics. They meet a wide range of specifications for a wide range of applications. The main applications include: those that use the piezoelectric effect (such as sensors and pickups), those that utilize resonance (such as transducers for ultrasonic motors and cleaning equipments), and those that utilize the electrostrictive effect (such as piezoelectric sound elements and displacement elements). In addition, they can be used as ultrasonic vibrators and transducers.

2010.03.19 9307PIEVOL04E

Evaluation of Transducer Characteristics

NEC TOKIN evaluates the characteristics of transducer materials based on a number of parameters.

1) Resonant Frequency

When an AC voltage is applied to the transducer and frequency f is varied to be in agreement with the natural frequency of the transducer, it vibrates very violently. This frequency is called resonance frequency fr.

A constant voltage circuit or a low voltage circuit was used for measurement of the resonance and anti-resonance frequencies. Recently. these frequencies can be measured easily with an impedance analyzer such as the HP4194A of Hewlett-Packard.

Resonance frequency fr obtained from the equivalent circuit near the resonance frequency and anti-resonance frequency fa can be expressed by the following equations:

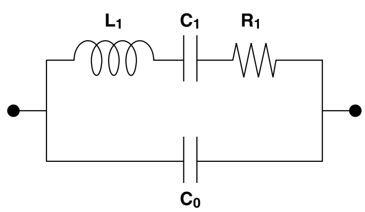


Fig. 1-1 Equivalent circuit of transducer

$$=1/\{2\pi\sqrt{\ _1\ _1}\}$$

$$=1/\{2\pi\sqrt{\ _1\ _0\ _1/(\ _1+\ _0)}\}$$

Practically, frequencies minimizing and maximizing the impedance shown in Fig. 2 are generally treated as fr and fa, respectively.

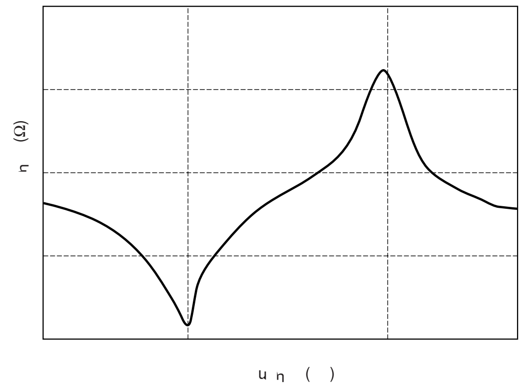


Fig. 1-2 Impedance characteristic of piezoelectric transducer

Resonant frequency fr can be defined in a number of different ways, depending on the mechanical structure and oscillation of the transducer.

) Radial vibration

$$= \frac{1}{\ }[\quad] \qquad (1)$$

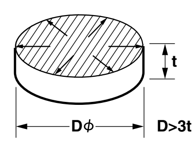


Fig. 1-3

Radial vibration is in the direction of the arrows. The coefficient of electromechanical coupling for this type of vibration us called Kr.

) **Lengthwise vibration**

$$= \frac{2}{\ell}[\quad] \qquad (2)$$

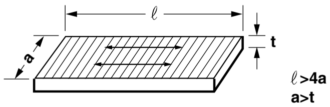


Fig. 1-4

The direction of vibration is perpendicular to the polarization direction; it is a simple vibration in one plane only. The coefficient of electromechanical coupling is known as K_{31}.

) **Longitudinal vibration**

$$= \frac{3}{\ell}[\quad] \qquad (3)$$

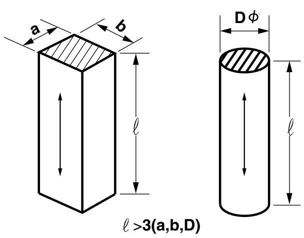


Fig. 1-5

The directions of polarization and vibration are the same, vibration is simple vibration. The electro-mechanical coupling coefficient is known as K_{33}.

) **Thickness vibration**

$$= \frac{4}{\quad}[\quad] \qquad (4)$$

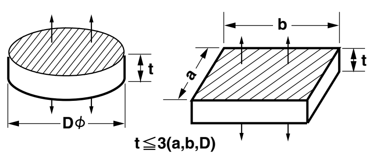


Fig. 1-6

Here, thickness is small compared with the area of the radiation plane; the effect of vibration is the same as that of longitudinal vibration. Generally, vibration is in two directions, and discrimination can be made between the two. The electromechanical coupling coefficient for this type of vibration is called Kt.

) **Shear vibration**

$$= \frac{5}{\quad}[\quad] \qquad (5)$$

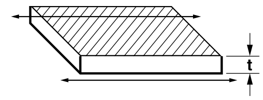


Fig. 1-7

The direction of vibration is the same as the polarization direction. Orientation of the drive field direction is perpendicular to it. A drive electrode is located perpendicular to the direction of polarization. The electromechanical coupling coefficient is expressed by K_{15}.

1: u η η η η (-)
2: u η η η η ∩ η (-)
3: u η η η η u η η (-)
4: u η η η ∩ η η (-)
5: u η η η ∩ η (-)
: u η ( )
ℓ : η ∩ , u η, η ( )
, : ∩ u u η (-)
: ∩ η , u , η ( )

2) Coefficient of electromechanical coupling

The coefficient of electromechanical coupling represents the mechanical energy accumulated in a ceramic or crystal; it is related to the total electrical input. This coefficient k can be calculated for each individual vibration mode by using the resonant (fr or fm) and antiresonant frequencies (fa or fn) and the applicable formula shown here:

$$= \sqrt{2.51\left(\frac{-}{\quad}\right)} \qquad (6)$$

$$_{31} = \sqrt{\frac{\quad}{- \ \eta}} \qquad (7)$$

$$= \frac{\pi}{2} \cdot \frac{\quad}{\quad}$$

$$k_{33} = \sqrt{\left(\frac{\pi}{2}\cdot\text{—}\right) \quad \left(\frac{\pi}{2}\cdot\text{—}\right)} \qquad (8)$$

$$k \ = \sqrt{\left(\frac{\pi}{2}\cdot\text{—}\right) \quad \left(\frac{\pi}{2}\cdot\text{—}\right)} \qquad (9)$$

$$k_{15} = \sqrt{\left(\frac{\pi}{2}\cdot\text{—}\right) \quad \left(\frac{\pi}{2}\cdot\text{—}\right)} \qquad (10)$$

η

k : ∩ η u η η η

k_{31}: ∩ η u η η η ∩ η

k_{33}: ∩ η u η η η u η η

k : ∩ η u η η ∩ - η η

k_{15}: ∩ η u η η ∩ η

: η η u η

: Aη η η u η

3) Relative dielectric constant

When the electric flux density caused by applying an electric field E between electrodes of a transducer under a constant stress is regarded as D, the relative dielectric constant is obtained by dividing the constant, defined by D/E=ε^T, by the vacuum dielectric constant ε_0. This relative dielectric constant is expressed by $\varepsilon^T_{33}/\varepsilon_0$ when the direction of polarization and applied electric field are the same; it is expressed by $\varepsilon^T_{11}/\varepsilon_0$ when these directions are perpendicular. Calculation of relative dielectric constant is shown in Eq. 11. Static capacitance is usually measured at 1kHz using an all-purpose bridge or a C meter.

$$\varepsilon_{33} / \varepsilon_0 = \frac{\quad}{\varepsilon_0} \qquad (11)$$

($\varepsilon^T_{11}/\varepsilon_0$ is also calculated using the same equation.)

η

ε_0 : η η η uu (8.854 10^{-12} /)

: η η ( )

: (^{2})

: η ( )

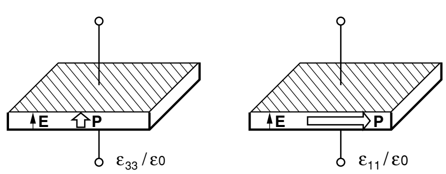


Fig.1-8

4) Young's modulus

For different modes of vibration, Young's modulus is calculated by Eq. 12, based on the sonic velocity and density of the material.

$$= \rho v^2 [\ /\ ^2] \qquad (12)$$

Where ρ: Density (kg/m³)
v(=2frℓ): Sonic velocity (m/sec.)
N: Newton

5) Mechanical Q

The mechanical Q is the "sharpness' of mechanical vibration at resonant frequency, and is calculated with Eq 13.

$$= \frac{\quad ^2}{2\pi \quad (\ ^2 - \ ^2)} \qquad (13)$$

η : η η u η ( )

: Aη η η u η ( )

: η η η (Ω)

: η ( )

Where a simpler method is called for, mechanical Q may be calculated with Eq. 14, using frequencies f_1 and f_2 which are each 3 dB from the resonant frequency.

$$= \frac{\quad}{1 - \ 2} \qquad (14)$$

The values shown for material characteristics in this catalog are calculated using Eq. 13.

6) Piezoelectric constant

There are two types of piezoelectric constants, the piezoelectric strain constant and the coefficient of voltage output.

) η η η

This is a measure of the strain that occurs when a specified electric field is applied to a material that is in the condition of zero stress. This constant is calculated with Eq. 15.

$$= \sqrt{\frac{\varepsilon}{\quad}} (\ /\ ) \qquad (15)$$

η : η ∩ η u η

ε : η η

: uη uu (η/ ^{2})

) ▼ u u η η

This is the intensity of the electric field caused when a specified amount of stress is applied to a material that is in the condition of zero displacement. Voltage output constant is calculated with Eq. 16.

$$= \frac{}{\varepsilon}(\blacktriangledown \cdot \quad / \quad) \quad (16)$$

Constants d and constants g can be d_{31}, d_{33}, or d_{15}, and g_{31}, g_{33}, or g_{15}, depending on the type of vibration.

7) Curie temperature

This is the temperature at which polarization disappears and the piezoelectric qualities are lost. It is also the temperature at which the value of the dielectric constant becomes maximum.

8) Temperature coefficient

The temperature coefficient is a measure of the variation of the resonant frequency and static capacitance with change in temperature. Temperature coefficient is calculated with Eqs. 17 and 18.

$$(\ ) = \frac{1}{\Delta} \cdot \frac{(\ _1) - (\ _2)}{\ _{20}} \times 10^6 (\quad /° \ ) \quad (17)$$

$$(\ ) = \frac{1}{\Delta} \cdot \frac{(\ _1) - (\ _2)}{\ _{20}} \times 10^6 (\quad /° \ ) \quad (18)$$

( ) : u η η η
u η (/)
(1) : η η u η u
1 ( )
(2) : η η u η u
2 ( )
20 : η η u η u
20 ( )
( ): u η
η (/)
(1): η ( ) u
1
(2): η ( ) u
2
20 : η 20 ( )
Δ : u η (2 1) ( )

9) Aging rate

The aging rate is an index of the change in resonant frequency and static capacitance with age. To calculate this rate, after polarization the electrodes of a transducer are shorted together, and are heated for a specified period of time. Measurements are taken of the resonant frequency and static capacity every 2^n days. (That is, at 1, 2, 4, and 8 days.) The aging rate is calculated with Eq. 19.

$$(A \quad) = \frac{1}{\ _2 - \ _1} \cdot \frac{\ _2 - \ _1}{\ _1} \quad (19)$$

(A) : A η η η u η
η
1, 2 : u η
1, 2 : η η u η
η 1 η 2
η

10) Density

The density is calculated with Eq. 20, after determining the volume and weight of the specified ceramic material.

$$= \frac{}{}(\quad / \quad ^3) \quad (20)$$

: η ( )
: u (3)

NEPEC® NPM Ceramics

Characteristics of Standard Materials

Table 1-1 shows the material characteristics of NEC TOKIN's standard NEPEC® NPM ceramic materials.

Notes

1. Frequency constants;
   - N1 : Radial frequency constant (fr×D)
   - N2 : Lengthwise frequency constant (fr×ℓ)
   - N3 : Longitudial frequency constant (fa×ℓ)
   - N4 : Thickness frequency constant (fa×ℓ)
   - N5 : Shear frequency constant (fa×ℓ)
2. The temperature and aging characteristics shown are values of radial vibration for a sample of 17.7ϕ×1.0t (mm) in size.
3. The values of Kr (electromechanical coupling coefficient) shown in parentheses are approximate values. All others are exact.

2010.03.19 9307PIEVOL04E

Table 1-1. Characteristics of Standard NEPEC® NPM Materials

Characteristics	Unit	N-6	N-61	N-8	N-10	N-21
		Material				
Relative dielectric constant	$\varepsilon_{33}/\varepsilon_0$	1400	1400	1100	5440	1800
	$\varepsilon_{11}/\varepsilon_0$	1350	1300	1400	5000	2000
Loss factor	ηδ (%)	0.3	0.3	0.4	2.0	2.0
Frequency constant	1 (-)	2160	2160	2240	2040	1960
	2 η ∩ (-)	1600	1570	1670	1410	1410
	3 η u η (-)	1510	1490	1520	1370	1310
	4 ∩ η (-)	1960	2010	2000	1800	1940
	5 ∩ (-)	970	1170	920	1110	860
Electro-mechanical coupling constant		(0.65) 0.55	(0.67) 0.56	(0.67) 0.56	(0.57) 0.50	(0.78) 0.62
	31 η	0.34	0.33	0.34	0.34	0.38
	33 u η	0.68	0.67	0.67	0.68	0.73
	∩ η	0.55	0.52	0.52	0.62	0.52
	15 ∩	0.71	0.66	0.78	0.66	0.77
Elastic constant	11 ($\times 10^{-12}$ 2/)	12.7	13.1	11.2	14.8	16.5
	33 ($\times 10^{-12}$ 2/)	15.4	15.6	15.2	18.1	19.9
	11 ($\times 10^{10}$ / 2)	7.9	7.6	8.9	6.8	6.1
	33 ($\times 10^{10}$ / 2)	6.5	6.4	6.6	5.5	5.0
Piezo-electric constant	31 ($\times 10^{-12}$ /▼)	-133	-132	-99	-287	-198
	33 ($\times 10^{-12}$ /▼)	302	296	226	635	417
	15 ($\times 10^{-12}$ /▼)	419	464	652	930	711
	31 ($\times 10^{-3}$▼ /)	-10.4	-10.7	-13.1	-6.0	-12.1
	33 ($\times 10^{-3}$▼ /)	23.5	23.8	30.0	13.2	25.4
	15 ($\times 10^{-3}$▼ /)	45.1	39.4	44.4	21.0	41.0
Poisson's ratio	δ	0.32	0.31	0.24	0.34	0.34
Temperature coefficient	( ) (/) - 20 20°	300	600	-250	200	-300
	20 60°	300	400	-550	900	-150
	( ) (/) - 20 20°	1800	700	3700	3800	3500
	20 60°	2300	3000	3600	3500	3000
Aging rate	(%/10)	0.4	0.4	0.5	0.5	0.1
	(%/10)	-2	-2	-5	-5	-5
Mechanical quality factor		1500	1800	1600	70	75
Curie temperature	( )	325	315	320	145	330
Density	($\times 10^{3}$ / 3)	7.77	7.79	7.72	8.00	7.82
Thermal expansion coefficient	($\times 10^{-7}$/) (u 200°)	30	12	11	14	29

Characteristics and Main Applications by Material

Table 1-2 shows characteristics and main applications by material. Use materials that match your use.

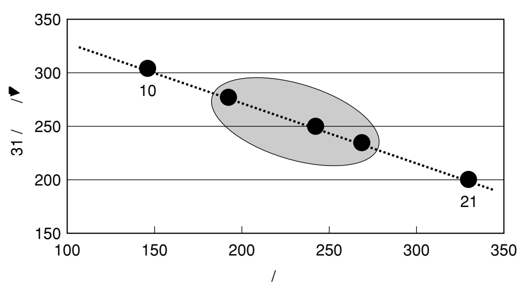
Table 1-2. General Characteristics and Main Applications

Item \ Material	N-6	N-61	N-8	N-10	N-21
Dielectric Constant	○	○	▲	●	○
Electromechanical Coupling Coefficient	○	○	○	○	●
Piezoelectric Modules				○	○
Piezoelectric Output Constant	○	○	○		○
Mechanical Quality Coefficient	○	○		▲	▲
Resonant Frequency Temperature Coefficient					
Dielectric Constant Temperature Coefficient		●			
Aging Characteristics					○
Main Applications	η u η η	η u η η	η η , u u η η u .	u , uη η ∩ u	∩ η , η η u , u η .

● = u u ○ = u ▲ = u

Materials for actuators

Actuator materials not listed in the catalog exemplified here. Please contact us for further details.

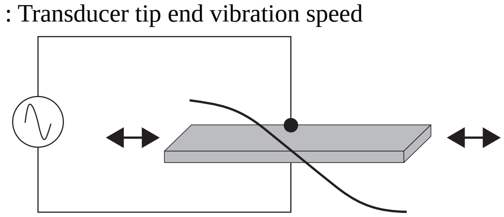


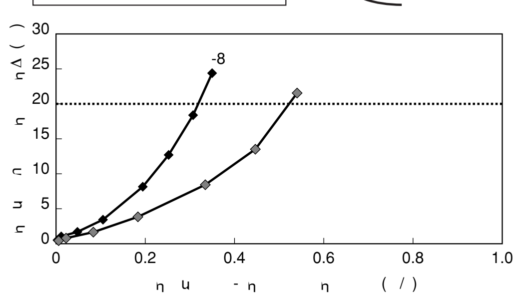
High-power piezoelectric Materials

The vibration energy of the piezoelectric transducer is in proportion to the square of the transducer tip end vibration speed.
There are high-power materials not listed in the catalog that do not generate heat at high vibration velocities. Please contact us for details.

Vibration energy $= \frac{1}{2}\ {}^{2}$

M : Equivalent mass
v : Transducer tip end vibration speed

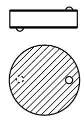
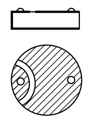
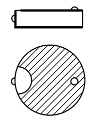
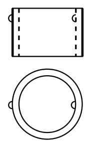
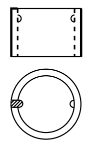




Terminal Layout

The three types of terminal layout are shown in Table 1-3 for the disc and cylindrical shapes.
Layout of terminals for the column, square plate, and square column shapes are the same as right. For inquiries about special terminal configurations,

Table 1-3

Terminals	P-terminal	S-terminal	O-terminal
Disc			
Cylinder			
Description	η ( ) η η η u .	η η u .	η η .

External Surface

NEC TOKIN transducers are coated for protection, for uniformity of the electromechanical interface, and to ensure an attractive external view. Table 1-4 shows the different types of surface coatings available. Select the coating that is best for your requirements.

Table 1-4. Types of External Coating

Coating	Features	Coating Surfaces	Standard Color
M Coating	η ∩ η; η . u ∩- η η η η η.	A u	
B Coating	B η; η . u u η η η .	A u	η (B)

Specification Example

	∩ ( )		( )		( )
η	38×34×30 36×31×30	−21 −21	24 25.8	0.25 0.25	26500 19600
	10×0.3 20×0.5 20×1.0 40×2.5 40×3.0 50×2.5 50×3.0 60×5.0	−21 −21 −8 −6 −6 −6 −6 −6	6400 4000 2100 54 54 43 43 36	0.57 0.6 0.55 0.6 0.6 0.6 0.6 0.6	3000 7000 2700 5600 4600 8900 7400 6500
u η	7×13.5 7×16.5 10×13.5 10×16.5	−21 −21 −21 −21	100 80 100 80	0.65 0.65 0.65 0.65	48 40 98 90
u	20×20×0.3 20×20×0.4 25×25×0.5 80×15×0.3 80×15×0.4 100×15×0.5 100×15×0.6	−21 −21 −21 −21 −21 −21 −21	6500 5000 4000 6500 5000 4000 3000	0.3 0.3 0.3 0.3 0.3 0.3 0.3	13500 10500 14000 42000 32500 33000 28500

Selected Material Characteristics

a) Temperature characteristics

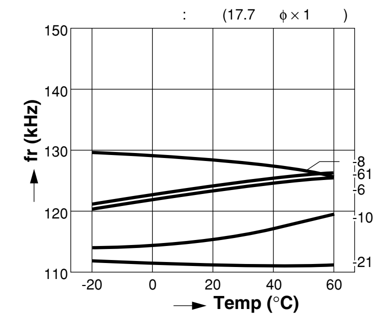


Fig.1-9. Variation in Resonant Frequency with Temperature

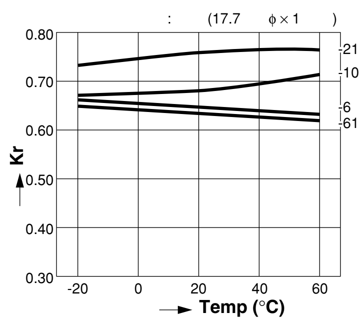


Fig.1-10. Variation in Electromechanical Coupling Coefficient with Temperature

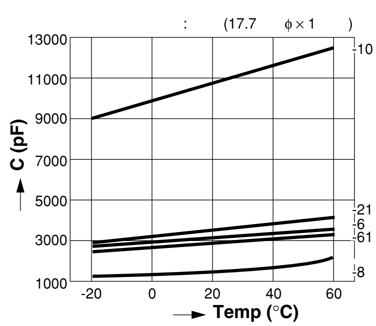


Fig.1-11. Variation in Static Capacitance with Temperature

b) Aging characteristics

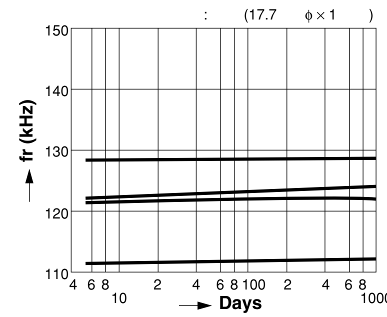


Fig.1-12. Variation in Resonant Frequency with Aging

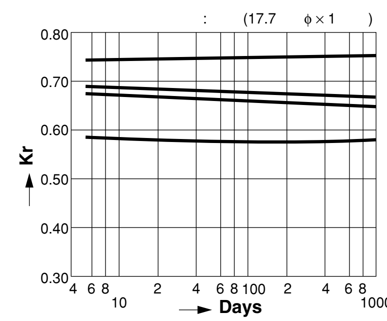


Fig.1-13. Variation in Electromechanical Coupling Coefficient with Aging

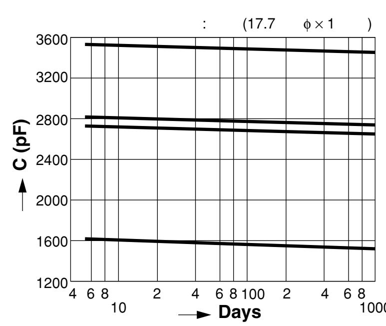


Fig.1-14. Variation in Static Capacitance with Aging

c) Thermal aging characteristics

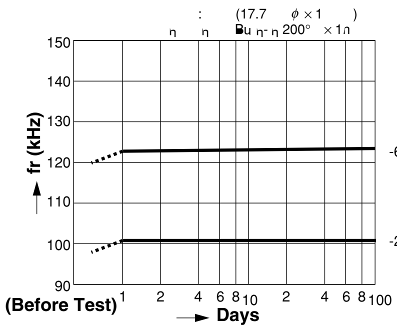


Fig.1-15. Variation in Resonant Frequency with Thermal Aging

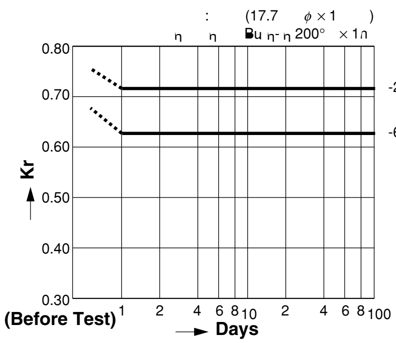


Fig.1-16. Variation in Electromechanical Coupling Coefficient with Thermal Aging

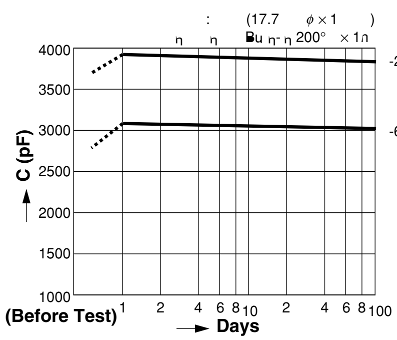


Fig.1-17. Variation in Static Capacitance with Thermal Aging

d) Characteristics of high-voltage aging

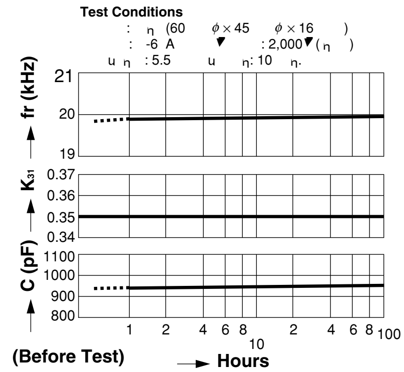


Fig.1-18. Variation in Dielectric Strength (Test 1)

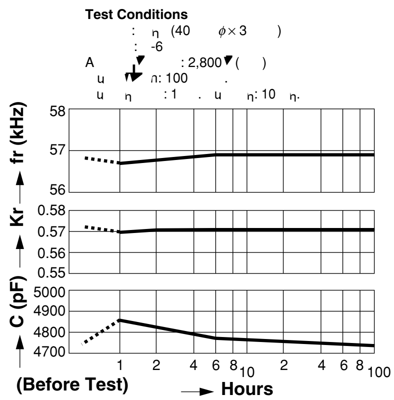


Fig.1-19. Variation in Dielectric Strength (Test 2)

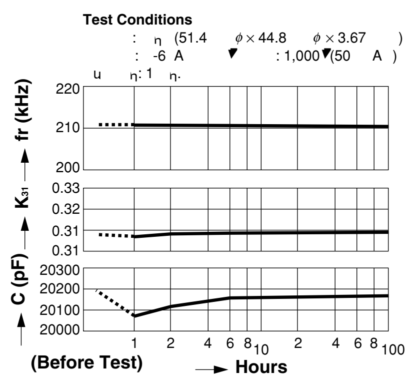
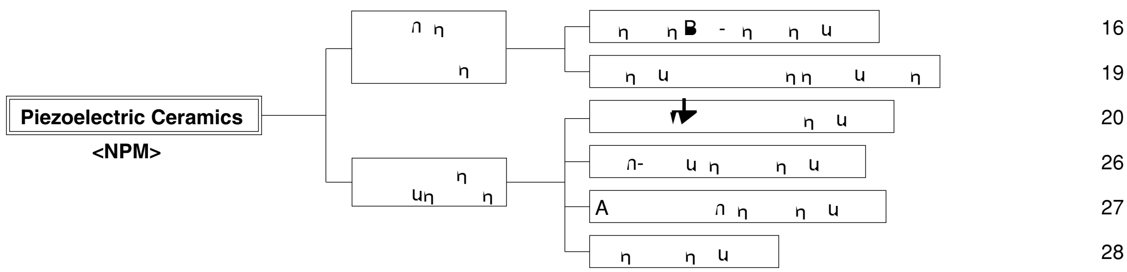


Fig.1-20. Variation in Dielectric Strength (Test 3)

Applications

The job of a transducer is to convert electrical energy into mechanical energy, and vice versa. And transducers using NEC TOKIN piezoelectric ceramics are uniquely suited to performing this job in a wide variety of applications. To help classify transducers, we divide their applications into two general areas: 1) conversion of electrical energy into mechanical energy for hydraulic or motive power, and 2) converting mechanical into electrical energy for communications and electronics.



2010.03.19 9307PIEVOL04E

Langevin Bolt-on Transducers

Outline

NEC TOKIN's Langevin-type transducers are used where powerful ultrasonic waves must be generated, such as in cleaning equipment, ultrasonic treatment machines, and welders for plastic. For application flexibility and ease of installation, these transducers are mounted in a structure that can be bolted almost anywhere.

NEC TOKIN's high-performance NEPEC® N-61 is excellent for use in these Langevin transducers. NEC TOKIN produces a number of this type of transducer, all featuring high quality and excellent output levels, and all based on a unique NEC TOKIN design.

Features

- High mechanical Q and excellent electro-acoustic conversion efficiency, providing a high output amplitude.
- Piezoelectric element offers a high speed of vibration
- N-61 ceramics have extended temperature range, ensuring good amplitude linearity.
- Bolt-on mounting gives fast, easy installation and high reliability.

Markings

Product models are classified as shown in the example here:

NBL 45 28 2 H

H = ɳ ɳ u ɳ; u u u ſ ſ ɳ ſ .
S = ſ ɳ u ɳ
2 = u ɳ (2 ɳ)
28 = ɳ ɳ u ɳ (28)
45 = u ɳ (ϕ 45)

<For Cleaning Equipment>

Specifications of Standard Models

Table 2-1

Item		Type	
		45282H-A	45402H-A
Resonant frequency	fo (kHz)	28.0	40.2
Dynamic admittance	Yo (mS)	40	15
Mechanical Q	Qm	500	500
Static capacitance	C (pF)	4000	4000
Maximum allowable velocity	V (cm / S)	40	50
Maximum allowable power	P (W)	50	50
Applications		ɳɳ u ɳ	

Note: u ɳ ſ ſ ɳ uɳ u ſ ɳ ɳ .

2010.03.19 9307PIEVOL04E

Shape and Dimensions

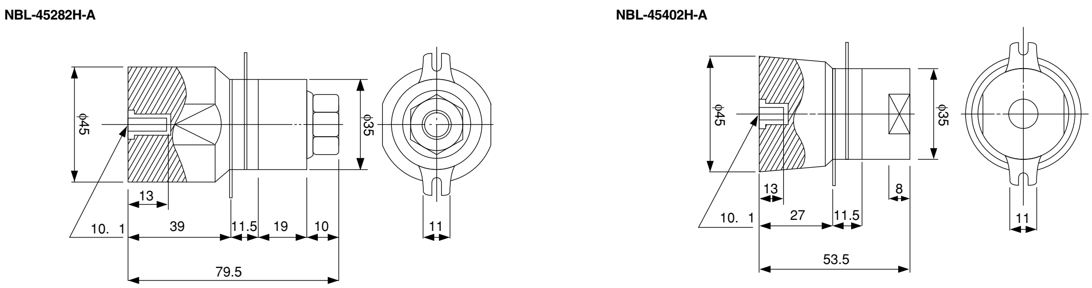


Fig. 2-1

Temperature Characteristics

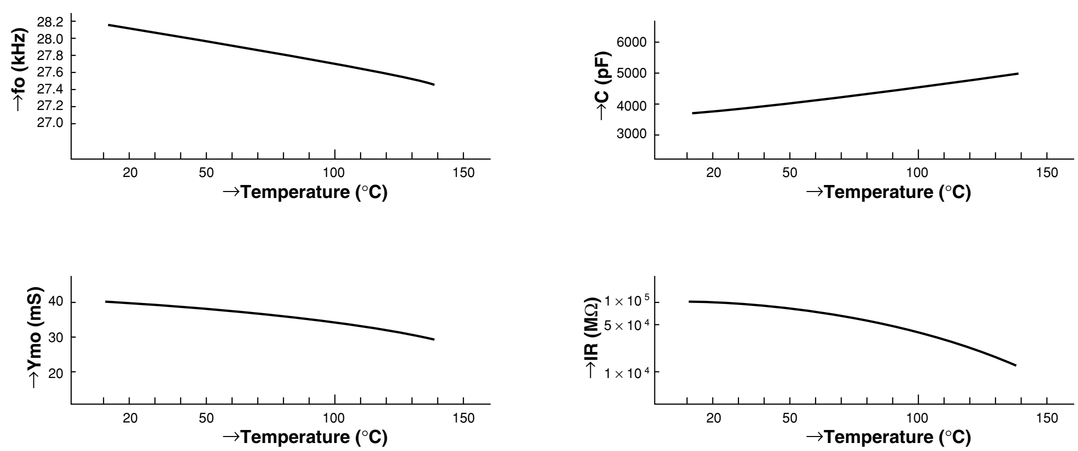


Fig. 2-2. Temperature Characteristics of NBL-45282H-A

<For Treatment Machines>

Specifications of Standard Models

Table 2-2

Item		Type	
		NBL15602S	NBL20602S
η η u η	fo (kHz)	60	60
η η	Ymo (mS)	25	20
∩ η ►	Qm	500	400
η	C (pF)	850	1250
u	V0-P (cm / S)	50	40
u A	P (W)	2.5	3.7
A η		η ∩η	

) u η u η η -

Shape and Dimensions

Fig. 2-3

Horn Installation Reference Example

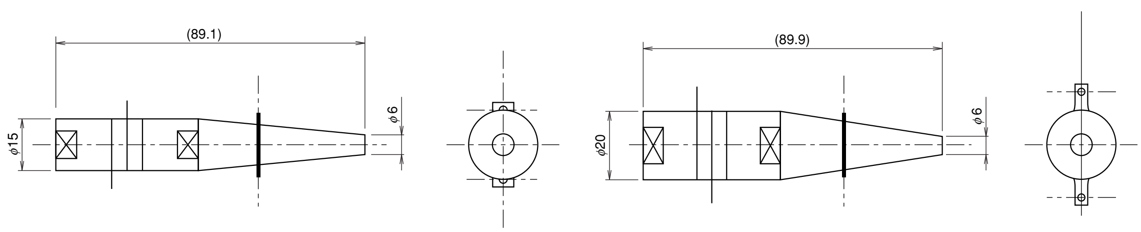


Fig. 2-4

Vibration

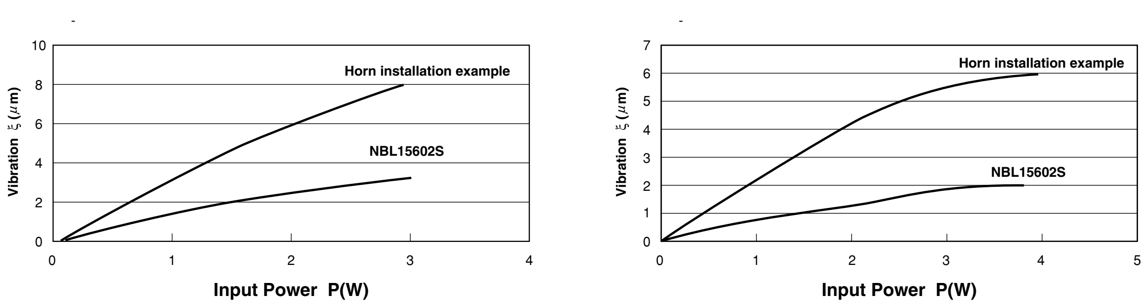


Fig. 2-5

2010.03.19 9307PIEVOL04E

Transducers for Cleaning Equipment

Outline

In the past, transducers for cleaning equipment have been found almost exclusively in ultrasonic cleaners for industrial and business use. Today, however, small cleaning equipment for glasses, false teeth, gemstones, etc. is increasingly found in individual households as well. NEC TOKIN's transducers for cleaning equipment utilize our N-6 material, providing ultrasonic generators that are compact and extraordinarily temperature-resistant.

Specifications

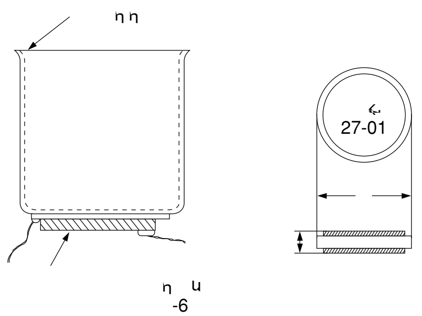


Fig. 2-6. Product Diagram

Specification Example

Table 2-3

D (mm)	t (mm)	fr (kHz)	Kr	C (PF)
40	2.5	54	0.60	5600
40	3.0	54	0.60	4600
50	2.5	43	0.60	8900
50	3.0	43	0.60	7400
60	5.0	36	0.60	6500

Temperature Characteristics

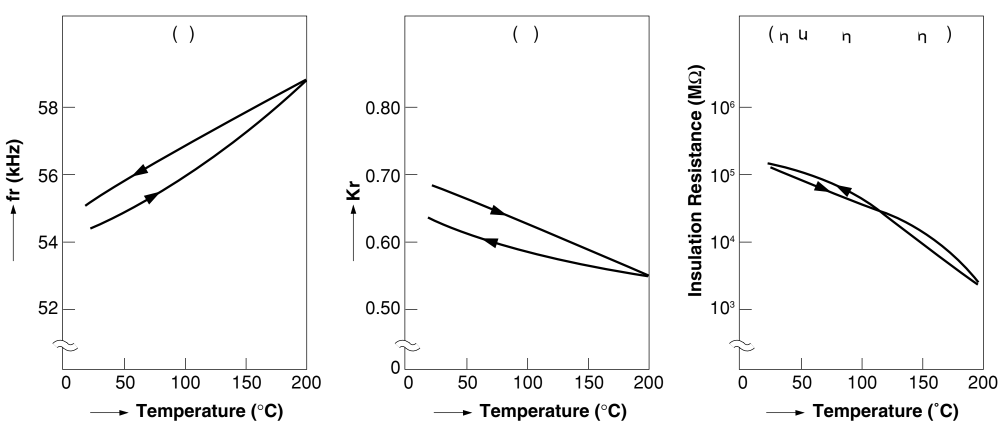


Fig. 2-7. Variation in N-6 Characteristics with Temperature

2010.03.19 9307PIEVOL04E

Molded Waterproof Transducers

Outline

Transducers that can withstand salt water and under-water pressures are used to generate ultrasonic signals for fish finders, sonar equipment, depth gauges, and Doppler-effect velocity and current meters.

NEC TOKIN's molded transducers are highly reliable, even in the face of severe underwater conditions. Completely waterproof, they offer excellent mechanical strength and temperature characteristics, thanks in part to their unique NEC TOKIN design and technology. By using a variety of different materials for our molded transducers, we can offer a large variety of frequency, input, and directivity characteristics.

Features

- High reliability, thanks to NEC TOKIN's own molding technology, including solid urethane rubber molding and baked neoprene rubber.
- Excellent noise characteristics.
- Wide range of frequencies and molding materials available.

Markings

Product models are classified as shown in the following example:

T GM 60-50 A-10 LA

: ∩ η , A: ▼η

η ∩ ( )

. η u η u A: 3, B: 2

η η u η ( )

η u u ( )

η : u η , : η , B : η

η u : ▼ , :

Specifications of Standard Models

Table 2-6

Model	Resonant Frequency (kHz)	Impedance (Ω) at Resonance	Static Capacitance (pF)	Insulation Resistance (MΩ)	Directivity	Shape
TGM60-40-10L	40	150 400	7500	500 η	50	A
TGM60-45-10L	45	150 400	7500	500 η	45	A
TGM60-50-10L	50	150 350	8000	500 η	44	A
TGM42-75-10L	75	200 600	3400	500 η	36	A
TGM80-75-12L	75	300 800	2500	500 η	20	A
TGM100-100-15L	100	200 400	4500	500 η	12	A
TGM50-200-10L	200	100 400	2400	500 η	11	A
TGM80-200-20L	200	50 200	5500	500 η	7	A
TGM100-200-20L	200	30 100	7500	500 η	6	A
TMM60-50-10LA	50	100 300	8000	500 η	44	B
TMM50-200-10LA	200	200 400	2500	500 η	11	B
TGM60-50A-15L	50	50 150	23000	500 η	12 ×44	
TGM50-200A-15L	200	70 150	5500	500 η	5 ×11	
TGM60-50B-12L	50	100 300	15000	500 η	13 ×44	
TGM46-68B-12L	68	50 200	12700	500 η	11 ×38	
TGM42-75B-12L	75	50 200	9000	500 η	11 ×36	
TGM50-200B-12L	200	150 400	4300	500 η	11	
NBM40-50-8LA	50	150 350	2800	500 η	60	
TBM50-200-8LA	200	200 450	2800	500 η	11	

Physical Characteristics

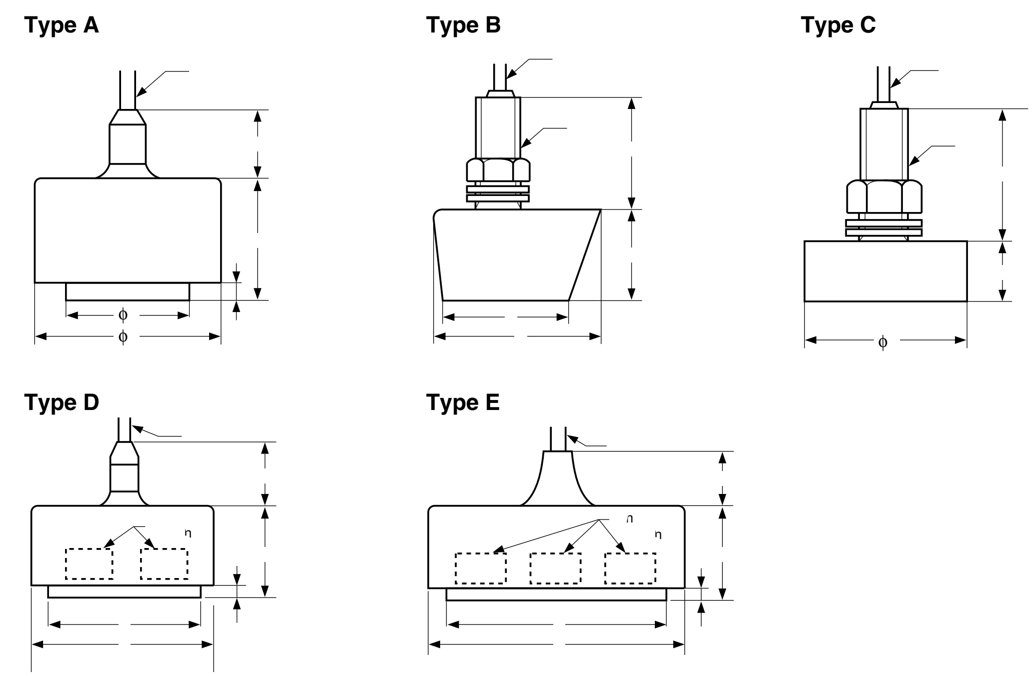
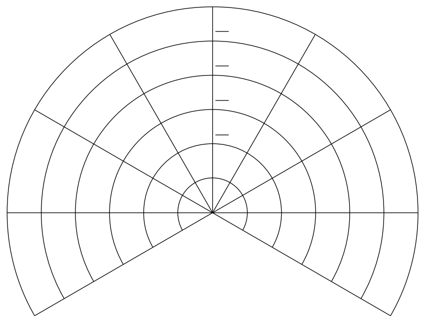
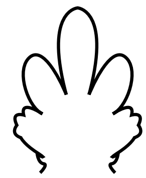


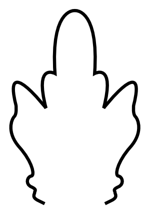
Fig. 2-10. Shape and Construction

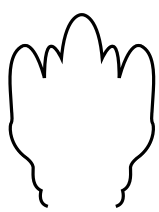
Table 2-7

Model	Dimensions a	b	c	d	e	f (cable)	Shape
TGM60-40-10L	69.5	89.5	5.0	78.0	60.0	ϕ11, - ∩ (∩ η)	A
TGM60-45-10L	69.5	89.5	5.0	78.0	60.0		
TGM60-50-10L	69.5	89.5	5.0	60.0	60.0		
TGM42-75-10L	47.8	61.0	4.0	43.0	27.0		
TGM80-75-12L	104.0	120.0	5.0	65.0	30.0		
TGM100-100-15L	120.0	130.0	4.0	55.0	40.0		
TGM50-200-10L	69.5	89.0	5.0	60.0	60.0		
TGM80-200-20L	100.0	120.0	7.0	45.0	30.0		
TGM100-200-20L	124.0	140.0	7.0	45.0	30.0		
TMM60-50-10LA	80.0	100.0	56	120	1.11 / η ∩	ϕ7, - ∩ (η)	B
TMM50-200-10LA							
TGM60-50A-15L	206.0	226.0	7.0	160.0	60.0	ϕ11, - ∩ (∩ η)	
TGM50-200A-15L							
TGM60-50B-12L	140.0	160.0	5.0	60.0	50.0	ϕ11, - ∩ (∩ η)	
TGM46-68B-12L							
TGM42-75B-12L							
TGM50-200B-12L							
NBM40-50-8LA		68.0	31.0	120.0	22 1.5	ϕ5, - ∩ (η)	
TBM50-200-8LA							









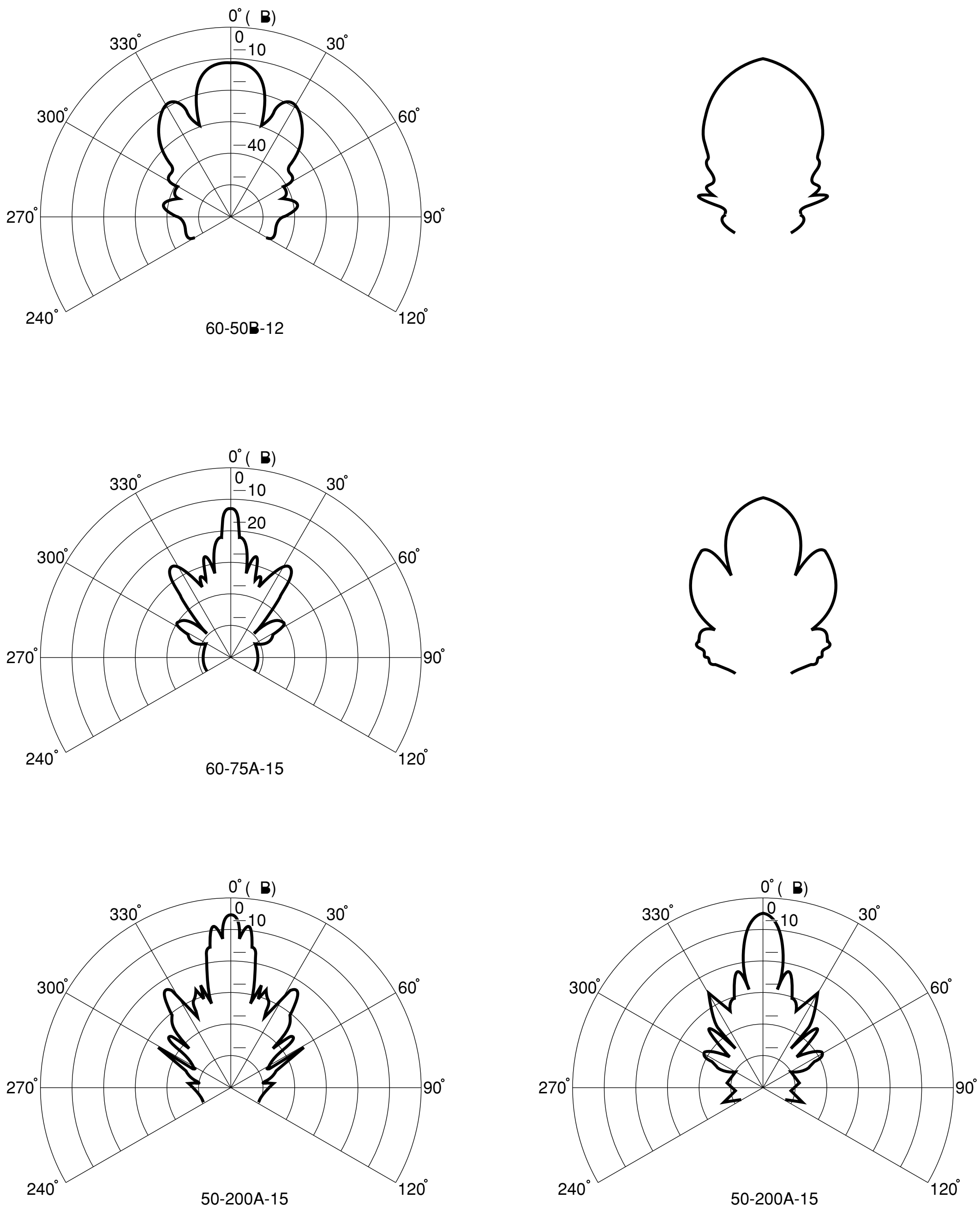
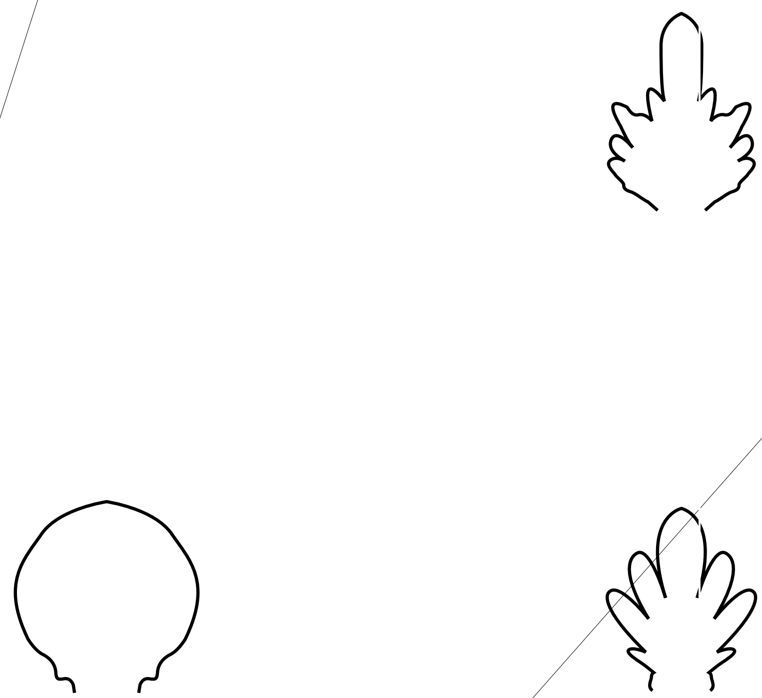


Fig. 2-11. Directvity

Typical Directivity Patterns (2)(dB)020



High-Frequency Transducers

Outline

Compared to ordinary piezoelectric transducers, these types operate at much higher frequencies: usually in the 1~10 MHz range. One of the primary applications of high-frequency transducers is as a sensor for flaw detection. Another important application area is medical equipment; in fact, with ultrasonic diagnosis becoming ever more widespread, HF piezoelectric transducers are the focus of increasing attention.

Here are some of the types of ultrasonic diagnosis that require HP transducers:

Doppler system:
- Fetus phonocardiographs
- Blood flowmeter

Pulse echo system:
- Tomography
  - Electron scanning
  - Mechanical scanning
- Cranial disease diagnosis
- Cardiac wall displacement measurement

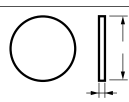
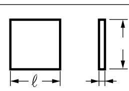
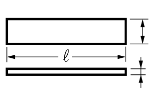
The vibration mode of these transducers is usually thickness resonance, and the frequency is high. For this reason, thin plate transducers with low impedance at resonance are needed. The dielectric constant of NEC TOKIN NEPEC® is low, and its impedance characteristics and other performance parameters are excellent for use in high-frequency transducers.

Features

- High impedance at resonant frequency.
- Excellent electromechanical coupling in thickness vibration mode.
- High sensitivity.
- Both thickness and radial vibration offer good anisotropic properties.
- Thickness resonance spurious emissions are low, and resolution is excellent.

Specifications Example

Table 2-8

Shape	Material	Dimensions (mm)			Characteristics				
		d	t	ℓ	( )	k	k_{31}	( )	η
	21	20	0.5		4,000	0.60		7,000	
	8	20	1.0		2,100	0.55		2,700	
	21	10	0.3		6,400	0.57		3,000	
	21	20	0.3	20	6,500		0.30	13,500	
	21	20	0.4	20	5,000		0.30	10,500	
	21	25	0.5	25	4,000		0.30	14,000	
	21	15	0.3	80	6,500		0.30	42,000	
	21	15	0.4	80	5,000		0.30	32,500	
	21	15	0.5	100	4,000		0.30	33,000	
	21	15	0.6	100	3,000		0.30	28,500	

Aerial Microphone Transducers

Outline

Ultrasonic aerial microphones generate ultrasonic waves that are radiated through the air and reflected from a target to measure distance. These microphones are used for traffic control, obstacle detection, as robot sensors, and in other similar applications.

Transducers for aerial microphones are of two types, bimorph and cylindrical , with different vibration modes. Such transducers are most often used together with a horn mounted in the radiation plane. NEC TOKIN aerial microphone transducers have good output power, receiving sensitivityon pla5PectimG92.6e

Sonar Transducers

Outline

Depth finders, underwater detectors, and fish finders all utilize the principle of sonar, in which sound waves are radiated through the water to detect and measure the distance to the target. Although there are differences in the resolution and distance capabilities required of sonar transducers, in general all should have the best possible sensitivity, resolution, directivity, and reliability. Sonar transducers fabricated of NEC TOKIN's superior NEPEC® material score high marks in all departments, and are available for a wide variety of applications.

Characteristics of Sonar Transducer Materials

Table 2-11

Transducer type	Vibration mode	Operating frequency	Main features	Remarks
a		70 500		
b		40 100		
c		100 500	A	
		10 200		
d		20 100		

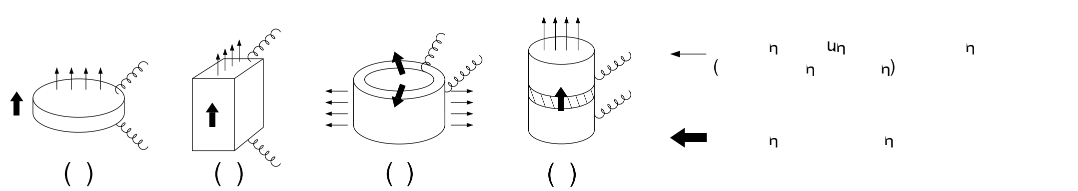


Fig. 2-13

Types and Features

Table 2-12

Material	K_{31}	$\varepsilon^T_{33}/\varepsilon_0$	Qm	Tc (˚C)	Features
N-6	0.34	1400	1500	325	
N-21	0.38	1800	75	300	