Devices thru Material Innovation

NEC/TOKIN

Vol. 04

Piezoelectric Ceramics

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INTRODUCTION

Increasingly, we can see the unique properties of mechanical vibration and ultrasonic waves put to use in many ways. And the single most important key to the effective monitoring or use of vibration is the transducer. Today's transducers are called on for standards of performance that are higher than ever before.

For best results in any application, the piezoelectric materials in the transducer should be selected with the specific use in mind. This catalog contains a wealth of information to help you evaluate transducer characteristics.

And when it comes to the materials themselves, look to NEC TOKIN's NEPEC® NPM piezoelectric ceramics. Using zicron and lead titanate as the main components, NEPEC materials have a wealth of features:

1) A wide selection range, especially for mechanical characteristics and degree of electromechanical coupling.
2) High stability against temperature and humidity variations and aging.
3) Remarkably fine ceramics that can be machined into a variety of sizes and shapes.
4) Excellent resistance to voltage, permitting transducers with polarization in any direction.
5) A wide range of potential uses.

This catalog describes NEC TOKIN's standard piezoelectric ceramics, and it also describes NEC TOKIN's line of transducers. If you cannot find the desired material characteristics or transducer for your application in these pages, please contact us directly; our engineering staff can work with you to develop materials for your purpose.

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.

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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:

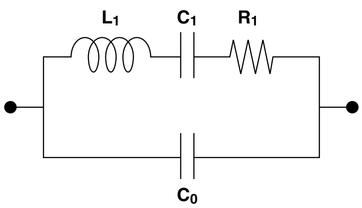

Fig. 1-1 Equivalent circuit of transducer

$$fr = 1/\{2\pi\sqrt{L_1C_1}\}$$

$$fa = 1/\{2\pi\sqrt{L_1C_0C_1/(C_1+C_0)}\}$$

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

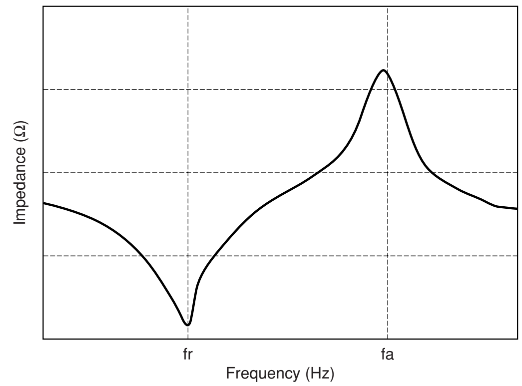

Fig. 1-2 Impedance characteristic of piezoelectric transducer

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

a) Radial vibration

$$fr = \frac{N_1}{D}[Hz] \cdots\cdots\cdots\cdots (1)$$

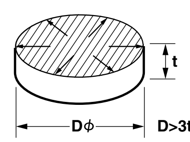

Fig. 1-3

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

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b) **Lengthwise vibration**

$$fr = \frac{N_2}{\ell}[Hz] \cdots\cdots\cdots\cdots (2)$$

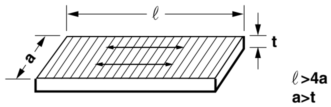

Fig. 1-4

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}.

c) **Longitudinal vibration**

$$fr = \frac{N_3}{\ell}[Hz] \cdots\cdots\cdots\cdots (3)$$

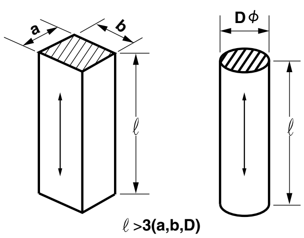

Fig. 1-5

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

d) **Thickness vibration**

$$fr = \frac{N_4}{t}[Hz] \cdots\cdots\cdots\cdots (4)$$

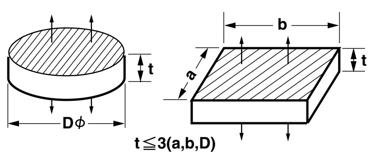

Fig. 1-6

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.

e) **Shear vibration**

$$fr = \frac{N_5}{t}[Hz] \cdots\cdots\cdots\cdots (5)$$

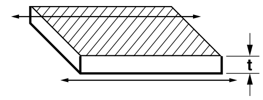

Fig. 1-7

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}.

Where

- N_1: Frequency constant of radial vibration (Hz-m)
- N_2: Frequency constant of lengthwise vibration (Hz-m)
- N_3 : Frequency constant of longitudinal vibration (Hz-m)
- N_4 : Frequency constant of thickness vibration (Hz-m)
- N_5 : Frequency constant shear vibration (Hz-m)
- D : Diameter of disc or column (m)
- ℓ : Length of plate, column, or cylinder (m)
- a,b: Width of square plate or column (Hz-m)
- t : Thickness of disc, square plate, or cylinder (m)

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:

$$Kr = \sqrt{2.51\left(\frac{fa - fr}{fr}\right)} \cdots\cdots\cdots\cdots (6)$$

$$K_{31} = \sqrt{\frac{r}{r - \tan r}} \cdots\cdots\cdots\cdots (7)$$

$$r = \frac{\pi}{2} \cdot \frac{fa}{fr}$$

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$$K_{33} = \sqrt{\left(\frac{\pi}{2}\cdot\frac{fr}{fa}\right)\cot\left(\frac{\pi}{2}\cdot\frac{fr}{fa}\right)} \cdots\cdots (8)$$

$$Kt = \sqrt{\left(\frac{\pi}{2}\cdot\frac{fr}{fa}\right)\cot\left(\frac{\pi}{2}\cdot\frac{fr}{fa}\right)} \cdots\cdots (9)$$

$$K_{15} = \sqrt{\left(\frac{\pi}{2}\cdot\frac{fr}{fa}\right)\cot\left(\frac{\pi}{2}\cdot\frac{fr}{fa}\right)} \cdots\cdots (10)$$

Where
- Kr : Electromechanical coupling coefficient for radial vibration
- K_{31}: Electromechanical coupling coefficient for lengthwise vibration
- K_{33}: Electromechanical coupling coefficient for longitudinal vibration
- Kt : Electromechanical coupling coefficient for thickness vibration
- K_{15}: Electromechanical coupling coefficient for shear vibration
- fr : Resonant frequency [Hz]
- fa : Antiresonant frequency [Hz]

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.

$$\varepsilon^T_{33} / \varepsilon_0 = \frac{tC}{\varepsilon_0 S} \cdots\cdots (11)$$

($\varepsilon^T_{11}/\varepsilon_0$ is also calculated using the same equation.)
Where
- ε_0 : Relative dielectric constant in vacuum (8.854×10^{-12} F/m)
- t : Distance between electrodes (m)
- S : Electrode area (m^2)
- C : Static capacitance (F)

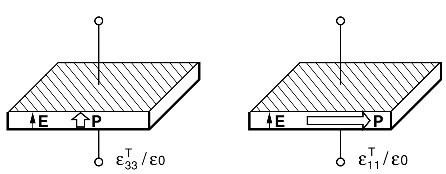

Fig.1-8

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.

$$Y^E = \rho v^2 \left[N/m^2\right] \cdots\cdots (12)$$

Where ρ: Density (kg/m^3)
ν(=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.

$$Qm = \frac{fa^2}{2\pi fr\ Zr\ C(fa^2 - fr^2)} \cdots\cdots (13)$$

Where fr : Resonant frequency (Hz)
fa : Antiresonant frequency (Hz)
Zr : Resonant resistance (Ω)
C : Static capacitance (F)

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.

$$Qm = \frac{fr}{f_1 - f_2} \cdots\cdots (14)$$

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.

a) Piezoelectric strain constant

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.

$$d = k\sqrt{\frac{\varepsilon^T}{Y^E}}(m/V) \cdots\cdots (15)$$

Where k : Coefficient of electromechanical coupling
ε^T : Dielectric constant
Y^E: Young's modulus (Newton/m^2)

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b) Voltage output constant

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.

$$g = \frac{d}{\varepsilon}(V \cdot m/N) \quad \cdots\cdots (16)$$

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.

$$TK(f) = \frac{1}{\Delta t} \cdot \frac{f(t_1) - f(t_2)}{f_{20}} \times 10^6 (PPm/{}^\circ C) \quad \cdots (17)$$

$$TK(C) = \frac{1}{\Delta t} \cdot \frac{C(t_1) - C(t_2)}{C_{20}} \times 10^6 (PPm/{}^\circ C) \quad \cdots (18)$$

Where
- TK(f) : Temperature coefficient of resonant frequency (PPm/˚C)
- f (t_1) : Resonant frequency at temperature t_1˚C(Hz)
- f (t_2) : Resonant frequency at temperature t_2˚C(Hz)
- f_{20} : Resonant frequency at temperature 20˚C(Hz)
- TK(C) : Temperature coefficient of static capacitance (PPm/˚C)
- C (t_1) : Static capacitance (F) at temperature t_1˚C
- C (t_2) : Static capacitance (F) at temperature t_2˚C
- C20 : Static capacitance at 20˚C(F)
- Δt : Temperature difference (t_2–t_1) (˚C)

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.

$$(AR) = \frac{1}{\log t_2 - \log t_1} \cdot \frac{X_{t2} - X_{t1}}{X_{t1}} \quad \cdots\cdots (19)$$

Where
- (AR) : Aging rate for resonant frequency or static capacitance
- t_1,t_2 : Number of days aged after polarization
- X_{t1},X_{t2} : Resonant frequency or static capacitance at t_1 and t_2 days after polarization

10) **Density**

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

$$D = \frac{W}{V}\left(kg/m^3\right) \quad \cdots\cdots (20)$$

Where
- W : Weight (kg) of ceramic material
- V : Volume (m^3) of material

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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.

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

Characteristics	Unit		N-6	N-61	N-8	N-10	N-21
Relative dielectric constant	$\varepsilon^T_{33}/\varepsilon_0$		1400	1400	1100	5440	1800
	$\varepsilon^T_{11}/\varepsilon_0$		1350	1300	1400	5000	2000
Loss factor	tanδ (%)		0.3	0.3	0.4	2.0	2.0
Frequency constant	N_1 [Radial]	(Hz-m)	2160	2160	2240	2040	1960
	N_2 [Lengthwise]	(Hz-m)	1600	1570	1670	1410	1410
	N_3 [Longitudinal]	(Hz-m)	1510	1490	1520	1370	1310
	N_4 [Thickness]	(Hz-m)	1960	2010	2000	1800	1940
	N_5 [Shear]	(Hz-m)	970	1170	920	1110	860
Electro-mechanical coupling constant	Kr [Radial]		(0.65) 0.55	(0.67) 0.56	(0.67) 0.56	(0.57) 0.50	(0.78) 0.62
	K_{31} [Transverse]		0.34	0.33	0.34	0.34	0.38
	K_{33} [Logitudinal]		0.68	0.67	0.67	0.68	0.73
	Kt [Thickness]		0.55	0.52	0.52	0.62	0.52
	K_{15} [Shear]		0.71	0.66	0.78	0.66	0.77
Elastic constant	S^E_{11} ($\times 10^{-12}m^2/N$)		12.7	13.1	11.2	14.8	16.5
	S^E_{33} ($\times 10^{-12}m^2/N$)		15.4	15.6	15.2	18.1	19.9
	Y^E_{11} ($\times 10^{10}N/m^2$)		7.9	7.6	8.9	6.8	6.1
	Y^E_{33} ($\times 10^{10}N/m^2$)		6.5	6.4	6.6	5.5	5.0
Piezo-electric constant	d_{31} ($\times 10^{-12}m/V$)		-133	-132	-99	-287	-198
	d_{33} ($\times 10^{-12}m/V$)		302	296	226	635	417
	d_{15} ($\times 10^{-12}m/V$)		419	464	652	930	711
	g_{31} ($\times 10^{-3}Vm/N$)		-10.4	-10.7	-13.1	-6.0	-12.1
	g_{33} ($\times 10^{-3}Vm/N$)		23.5	23.8	30.0	13.2	25.4
	g_{15} ($\times 10^{-3}Vm/N$)		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	TK (fr) (PPm/°C)	- 20~20°C	300	600	-250	200	-300
		20~60°C	300	400	-550	900	-150
	TK (°C) (PPm/°C)	- 20~20°C	1800	700	3700	3800	3500
		20~60°C	2300	3000	3600	3500	3000
Aging rate	fr (%/10 Years)		0.4	0.4	0.5	0.5	0.1
	C (%/10 Years)		-2	-2	-5	-5	-5
Mechanical quality factor	Qm		1500	1800	1600	70	75
Curie temperature	Tc (°C)		325	315	320	145	330
Density	D ($\times 10^3kg/m^3$)		7.77	7.79	7.72	8.00	7.82
Thermal expansion coefficient	($\times 10^{-7}$/°C) (Room Temperature ~200°C)		30	12	11	14	29

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Characteristics and Main Applications by Material

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

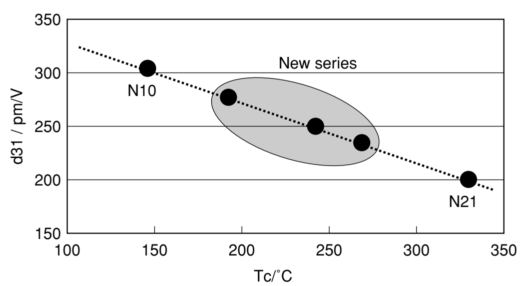
Table 1-2. General Characteristics and Main Applications

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	Transducers to generate ultrasonic signals, pressure generating elements and medical equipment transducers.			Pickups, microphones, speakers, underwater receiving transducers, and other acoustic equipment.	

● = Particularly good value ○ = Good value ▲ = Lower value

Materials for actuators

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

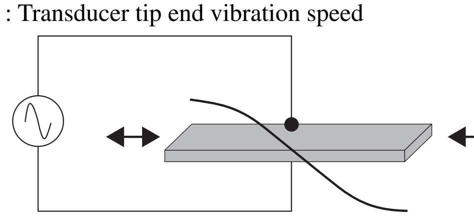


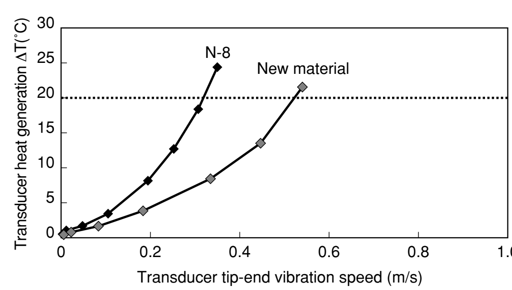
High-power piezoelectric Materials

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 $P = \frac{1}{2}Mv^2$

M : Equivalent mass
v : Transducer tip end vibration speed





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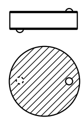
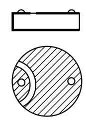
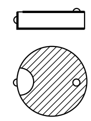
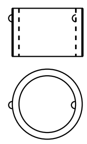
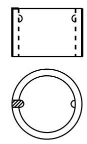
Terminal Layout

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	Terminals (solder dots) provided on positive and negative electrode surfaces.	Negative electrode terminal is available on positive electrode surface.	Negative electrode terminal is available on side face.

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	Synthetic resin; resists water and oil. Suitable for fish-finding sonars and air excitation.	All surfaces are coated	Silver gray
B Coating	Bakelite resin; resists solvents. Suitable for ultrasonic cleaning.	All surfaces are coated	Dark brown (Bakelite color)

Specification Example

	Shape(mm)	Material	fr(kHz)	K	C(pF)
Cylinder	NR 38×34×30	N−21	24	0.25	26500
	36×31×30	N−21	25.8	0.25	19600
Disc	ND 10×0.3	N−21	6400	0.57	3000
	20×0.5	N−21	4000	0.6	7000
	20×1.0	N−8	2100	0.55	2700
	40×2.5	N−6	54	0.6	5600
	40×3.0	N−6	54	0.6	4600
	50×2.5	N−6	43	0.6	8900
	50×3.0	N−6	43	0.6	7400
	60×5.0	N−6	36	0.6	6500
Column	ND 7×13.5	N−21	100	0.65	48
	7×16.5	N−21	80	0.65	40
	10×13.5	N−21	100	0.65	98
	10×16.5	N−21	80	0.65	90
Square Plate	NS 20×20×0.3	N−21	6500	0.3	13500
	20×20×0.4	N−21	5000	0.3	10500
	25×25×0.5	N−21	4000	0.3	14000
	80×15×0.3	N−21	6500	0.3	42000
	80×15×0.4	N−21	5000	0.3	32500
	100×15×0.5	N−21	4000	0.3	33000
	100×15×0.6	N−21	3000	0.3	28500

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Selected Material Characteristics

a) Temperature characteristics

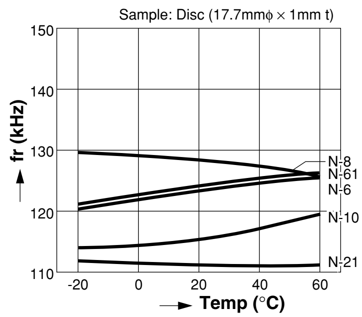

Fig.1-9. Variation in Resonant Frequency with Temperature

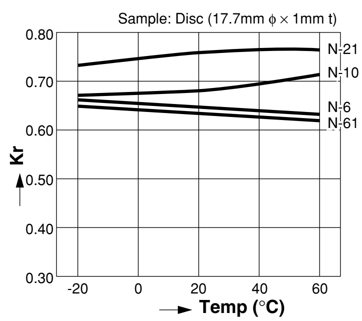

Fig.1-10. Variation in Electromechanical Coupling Coefficient with Temperature

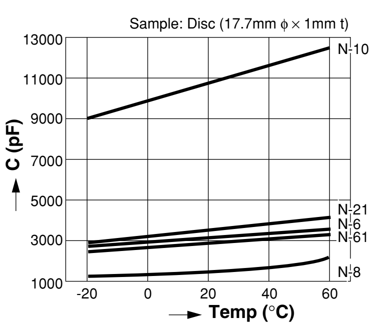

Fig.1-11. Variation in Static Capacitance with Temperature

b) Aging characteristics

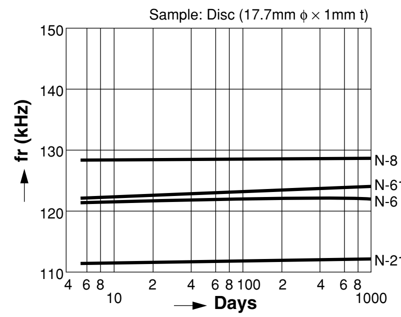

Fig.1-12. Variation in Resonant Frequency with Aging

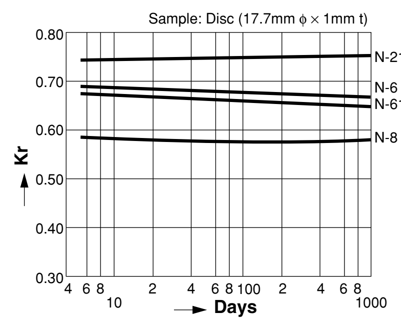

Fig.1-13. Variation in Electromechanical Coupling Coefficient with Aging

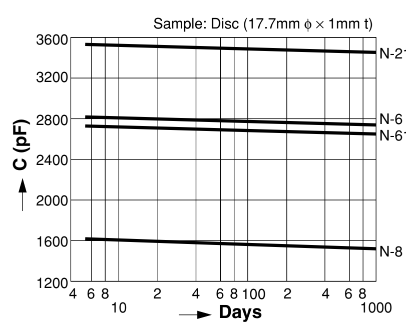

Fig.1-14. Variation in Static Capacitance with Aging

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c) Thermal aging characteristics

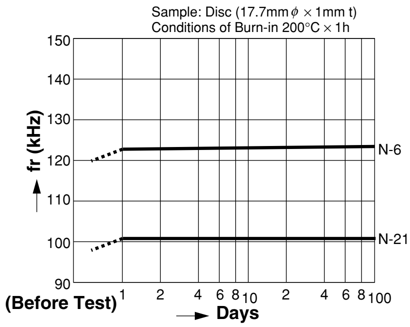

Fig.1-15. Variation in Resonant Frequency with Thermal Aging

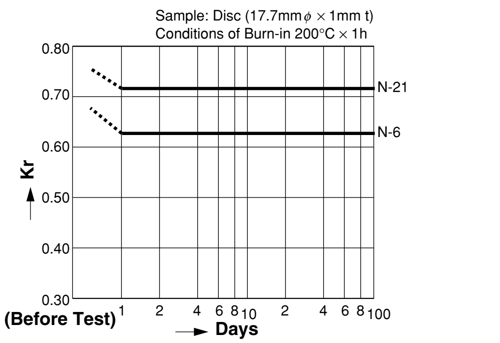

Fig.1-16. Variation in Electromechanical Coupling Coefficient with Thermal Aging

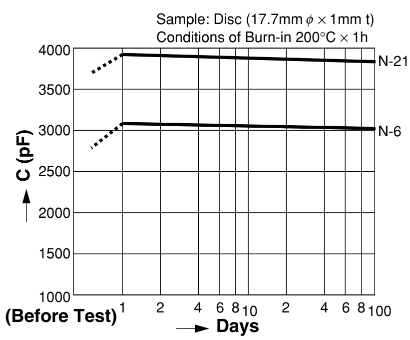

Fig.1-17. Variation in Static Capacitance with Thermal Aging

d) Characteristics of high-voltage aging

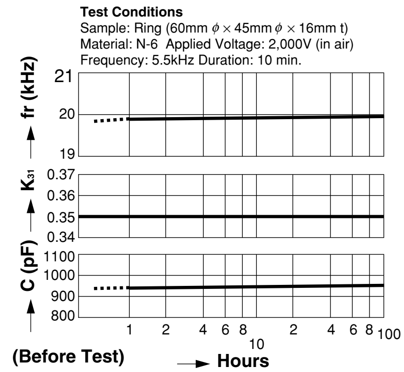

Fig.1-18. Variation in Dielectric Strength (Test 1)

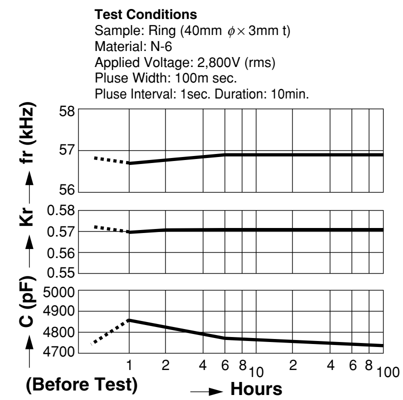

Fig.1-19. Variation in Dielectric Strength (Test 2)

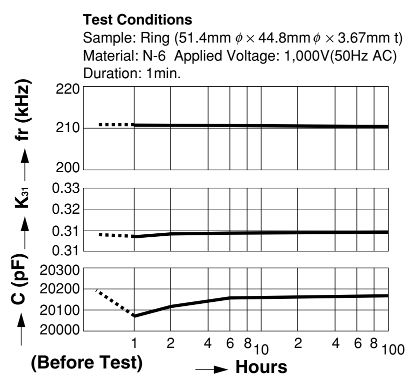

Fig.1-20. Variation in Dielectric Strength (Test 3)

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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.

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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** = Horn construction; output surface has step or horn shape.
- **S** = Straight construction
- **2** = Number of piezoelectric elements (2 elements)
- **28** = Resonant frequency (28kHz)
- **45** = Diameter of acoustic wave radiation (φ 45mm)

<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		Cleaning Equipment	

Note: Maximum allowable power is based on the data where one unit is measured with a water load on one side.

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Shape and Dimensions

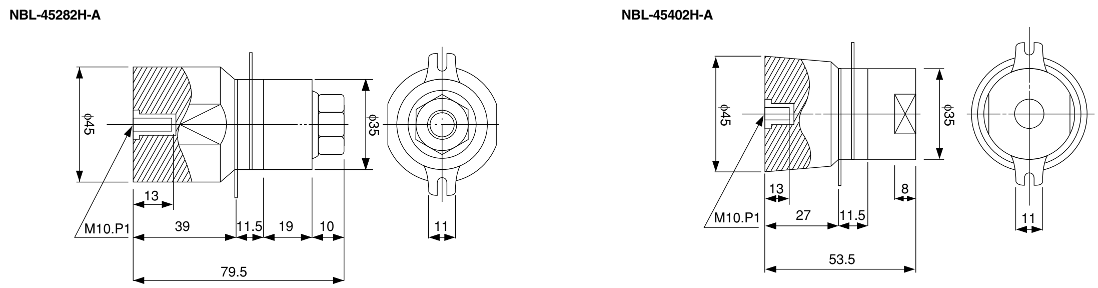

Fig. 2-1

Temperature Characteristics

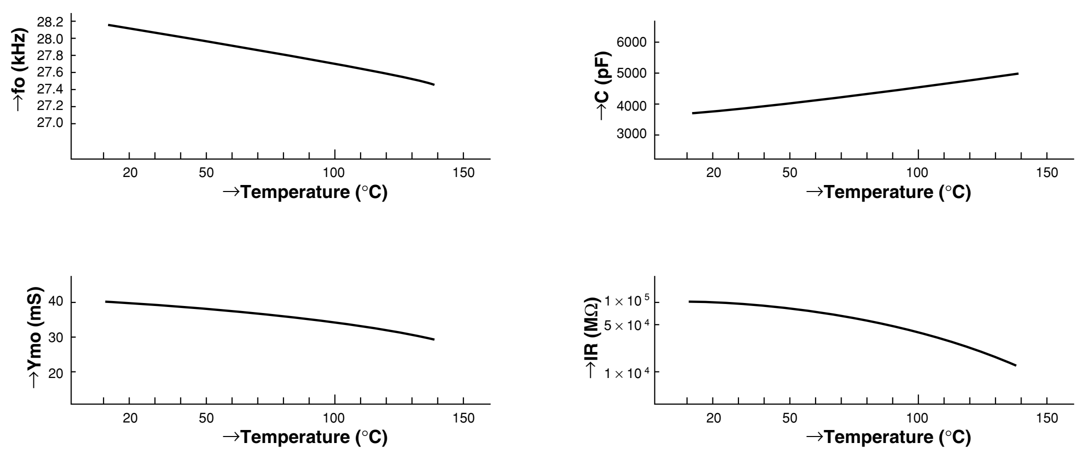

Fig. 2-2. Temperature Characteristics of NBL-45282H-A

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<For Treatment Machines>

Specifications of Standard Models

Table 2-2

Item		Type: NBL15602S	Type: NBL20602S
Resonant frequency	**fo (kHz)**	60	60
Dynamic admittance	**Ymo (mS)**	25	20
Mechanical Q	**Qm**	500	400
Static capacitance	**C (pF)**	850	1250
Maximum allowable velocity	**$V_{0\text{-}P}$ (cm / S)**	50	40
Maximum Allowable power	**P (W)**	2.5	3.7
Applications		Treatment Machines	

Note) Maximum allowable input in no-load state

Shape and Dimensions

NBL15602S **NBL20602S**

Fig. 2-3

Horn Installation Reference Example

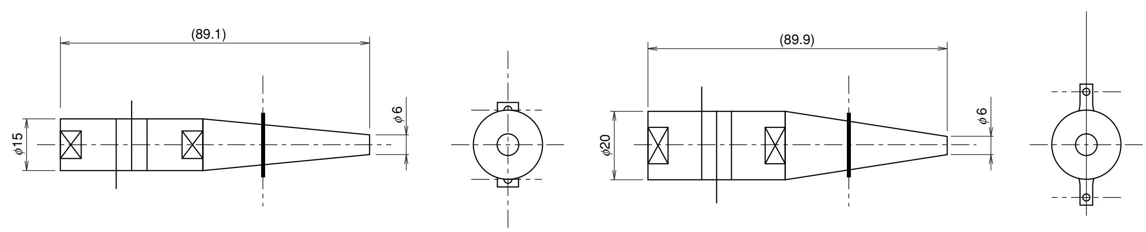

Fig. 2-4

Vibration

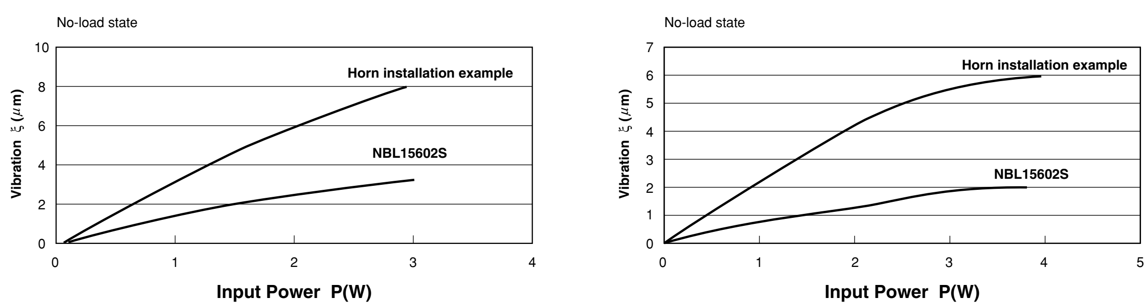

Fig. 2-5

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

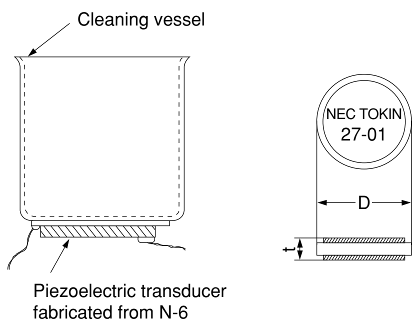

Fig. 2-6. Product Diagram

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

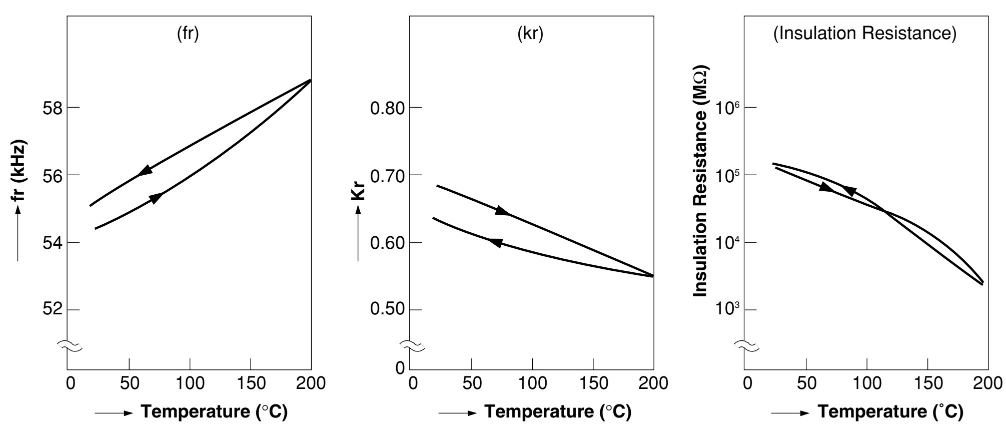

Fig. 2-7. Variation in N-6 Characteristics with Temperature

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Molded Waterproof Transducers

Outline

Transducers that can withstand salt water and underwater 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

- LA — Cable type L: Chloroprene, LA: Vinyl
- 10 — Cable length (m)
- A — No. of transducers included A: 3, B: 2
- 50 — Resonant frequency (kHz)
- 60 — Transducer outside diameter (mm)
- GM — Molding material GM: Rubber molding, MM: Metal molding, BM: Plastic molding
- T — Transducer material T: VPT, N: NPM

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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 and over	50°	A
TGM60-45-10L	45	150 ~ 400	7500	500 and over	45°	A
TGM60-50-10L	50	150 ~ 350	8000	500 and over	44°	A
TGM42-75-10L	75	200 ~ 600	3400	500 and over	36°	A
TGM80-75-12L	75	300 ~ 800	2500	500 and over	20°	A
TGM100-100-15L	100	200 ~ 400	4500	500 and over	12°	A
TGM50-200-10L	200	100 ~ 400	2400	500 and over	11°	A
TGM80-200-20L	200	50 ~ 200	5500	500 and over	7°	A
TGM100-200-20L	200	30 ~ 100	7500	500 and over	6°	A
TMM60-50-10LA	50	100 ~ 300	8000	500 and over	44°	B
TMM50-200-10LA	200	200 ~ 400	2500	500 and over	11°	B
TGM60-50A-15L	50	50 ~ 150	23000	500 and over	12°×44°	E
TGM50-200A-15L	200	70 ~ 150	5500	500 and over	5°×11°	E
TGM60-50B-12L	50	100 ~ 300	15000	500 and over	13°×44°	D
TGM46-68B-12L	68	50 ~ 200	12700	500 and over	11°×38°	D
TGM42-75B-12L	75	50 ~ 200	9000	500 and over	11°×36°	D
TGM50-200B-12L	200	150 ~ 400	4300	500 and over	11°	D
NBM40-50-8LA	50	150 ~ 350	2800	500 and over	60°	C
TBM50-200-8LA	200	200 ~ 450	2800	500 and over	11°	C

Physical Characteristics

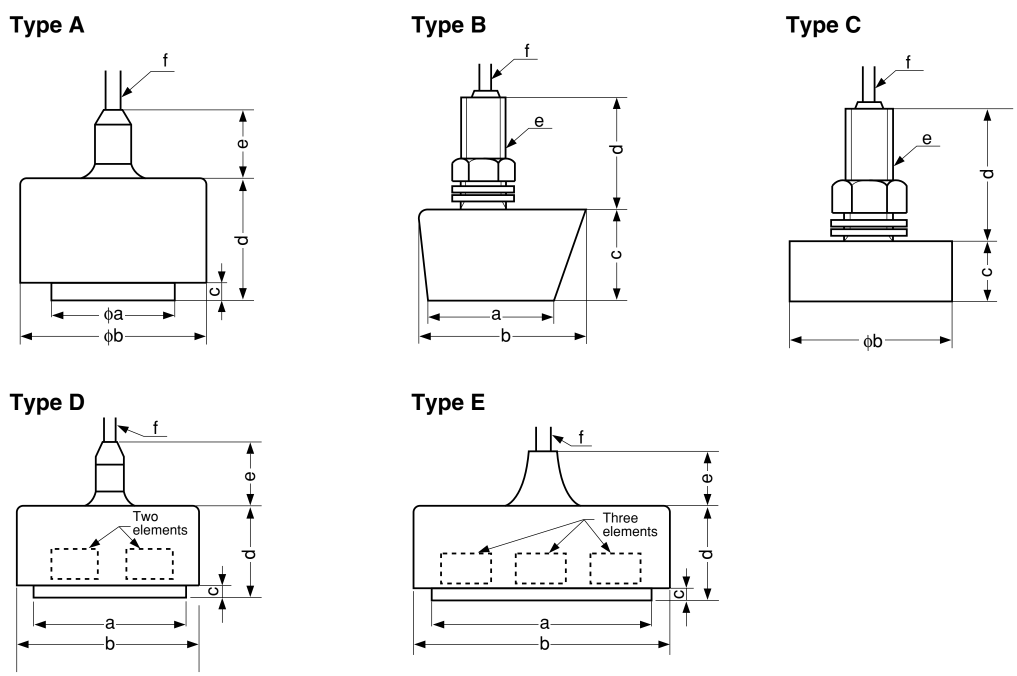

Fig. 2-10. Shape and Construction

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	φ 11, two-core shield captire cable (chloroprene)	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 TMM50-200-10LA	80.0	100.0	56	120	W • 1.11d/ inch	φ 7, two-core shield captire cable (vinyl)	B
TGM60-50A-15L TGM50-200A-15L	206.0	226.0	7.0	160.0	60.0	φ 11, two-core shield captire cable (chloroprene)	E
TGM60-50B-12L TGM46-68B-12L TGM42-75B-12L TGM50-200B-12L	140.0	160.0	5.0	60.0	50.0	φ 11, two-core shield captire cable (chloroprene)	D
NBM40-50-8LA TBM50-200-8LA	–	68.0	31.0	120.0	M • 22 P1.5	φ 5, two-core shield captire cable (vinyl)	C

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Typical Directivity Patterns (1)

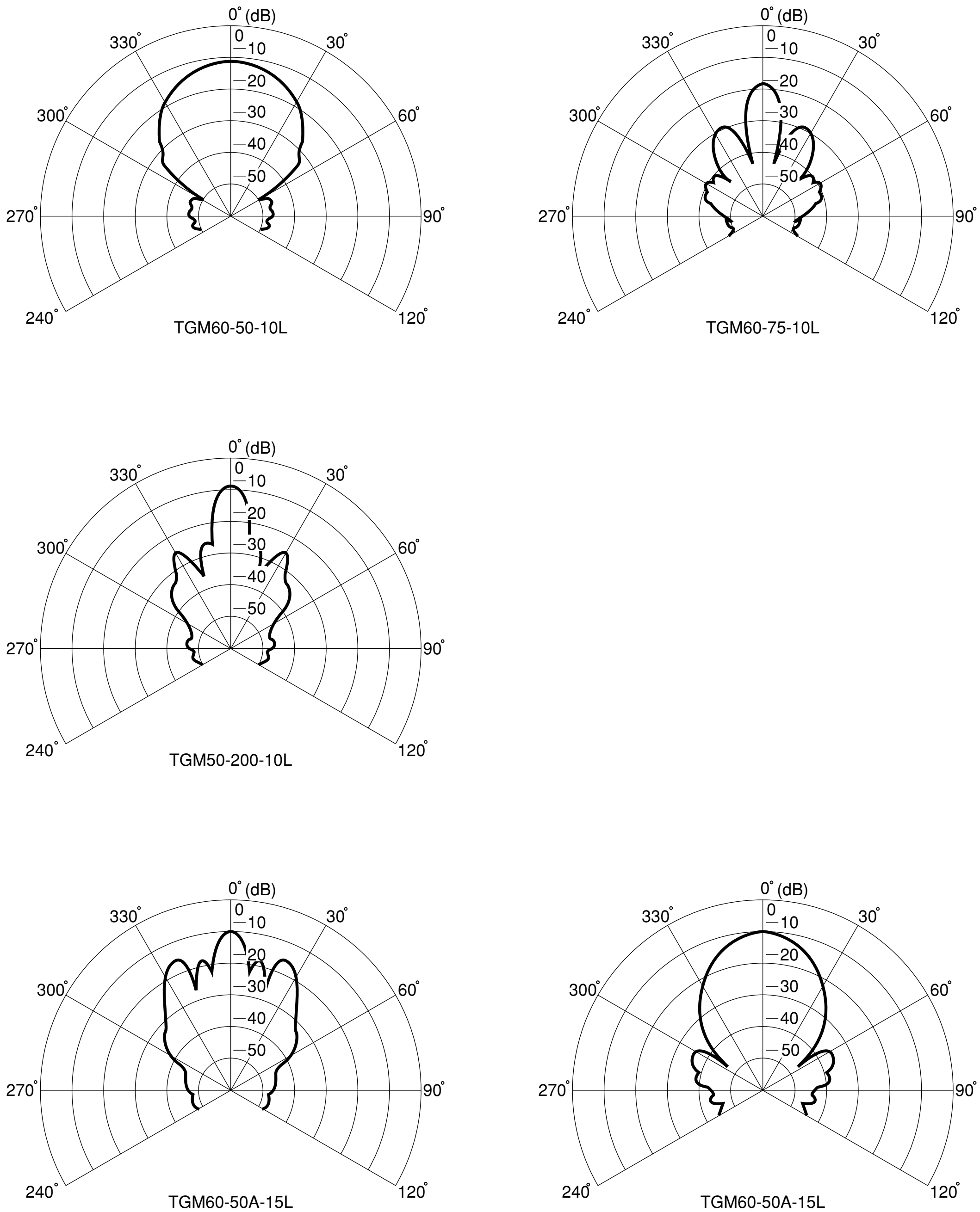

Fig. 2-11. Directvity

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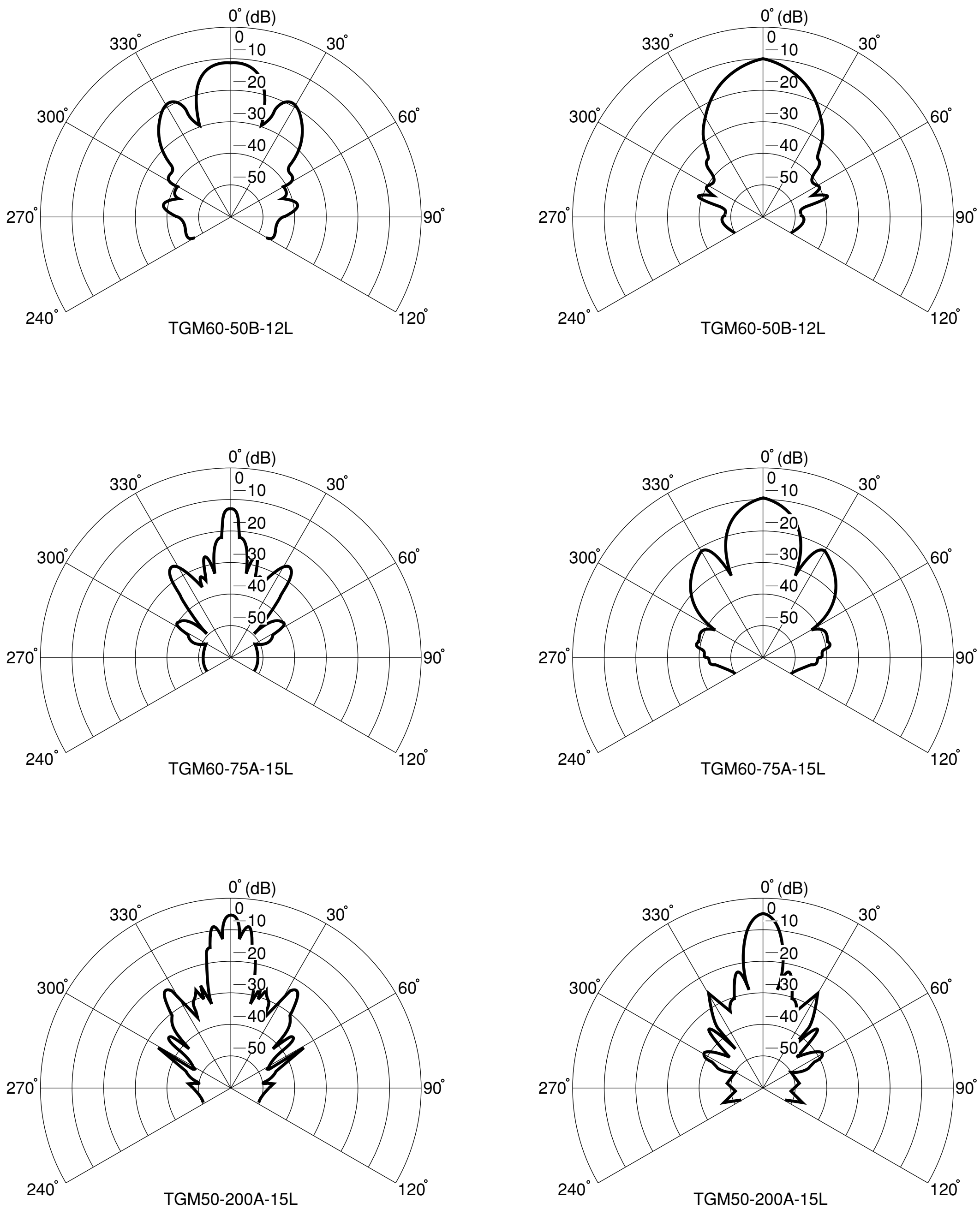

Fig. 2-11. Directvity

Typical Directivity Patterns (2)

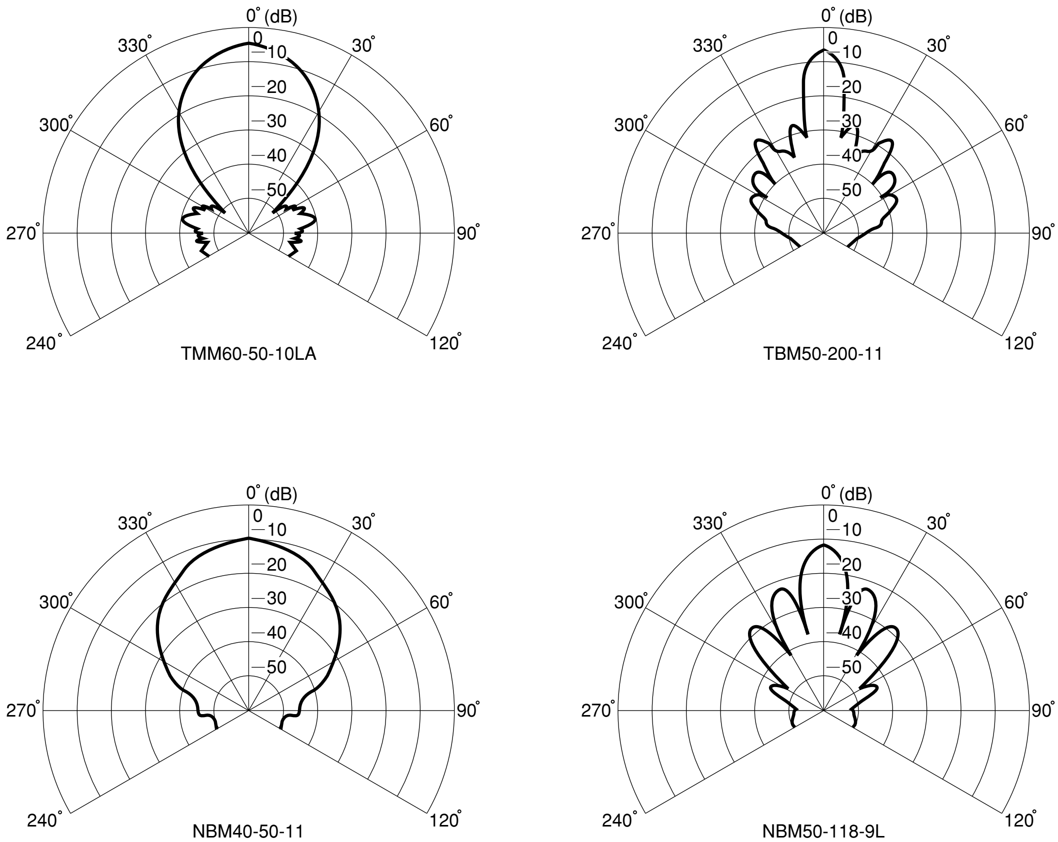

Fig. 2-11. Directivity

Note: Transducers with non-standard shapes and dimensions are also available. For inquiries, see page 34.

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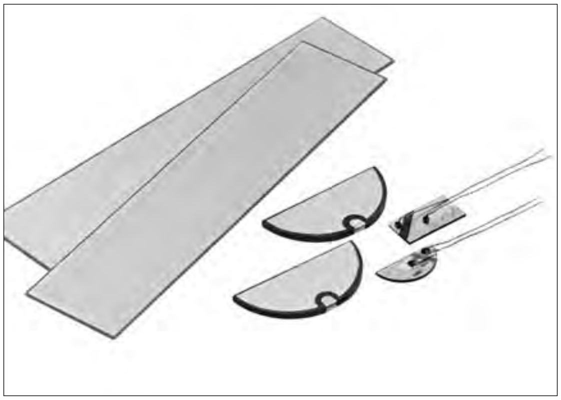
High-Frequency Transducers



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.

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:

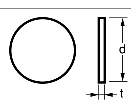
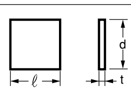
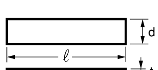
Doppler system:
- Fetus phonocardiographs
- Blood flowmeter

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.

Specifications Example

Table 2-8

Shape	Material	Dimensions (mm)			Characteristics				
		d	t	ℓ	f_r (kHz)	Kr	K_{31}	C (PF)	Terminal
	21	20	0.5	–	4,000	0.60	–	7,000	S
	8	20	1.0	–	2,100	0.55	–	2,700	S
	21	10	0.3	–	6,400	0.57	–	3,000	S
	21	20	0.3	20	6,500	–	0.30	13,500	P
	21	20	0.4	20	5,000	–	0.30	10,500	P
	21	25	0.5	25	4,000	–	0.30	14,000	P
	21	15	0.3	80	6,500	–	0.30	42,000	P
	21	15	0.4	80	5,000	–	0.30	32,500	P
	21	15	0.5	100	4,000	–	0.30	33,000	P
	21	15	0.6	100	3,000	–	0.30	28,500	P

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Aerial Microphone Transducers

Outline

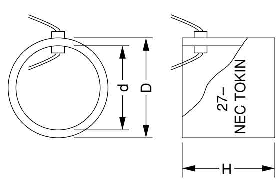
Ultrasonic aerial microphones generate ultrasonic waves that are radiated through the air and reflected from a target to measure distance. These microphones are used for traffic control, obstacle detection, as robot sensors, and in other similar applications.

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 sensitivity and directivity-all important in this type of application.

Features

- Good temperature characteristics.
- Cylindrical transducers are moisture-resistant, ensuring stable operation outdoors.
- High mechanical coupling, high sensitivity.

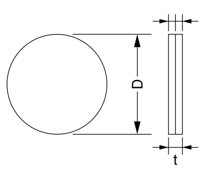
Specifications of Standard Models



Shape

Table 2-9. N-21 Specification Example

D (mm)	d (mm)	H (mm)	fr (kHz)	K	C (PF)
38	34	30	23.7	0.25	28000
36	31	30	25.8	0.25	19600



Shape

Table 2-10. N-6 Specification Example

D (mm)	t (mm)	fr (kHz)	Δf (kHz)	C (PF)
18.7	1.5	23.5	2.0	2100

Circuit Example

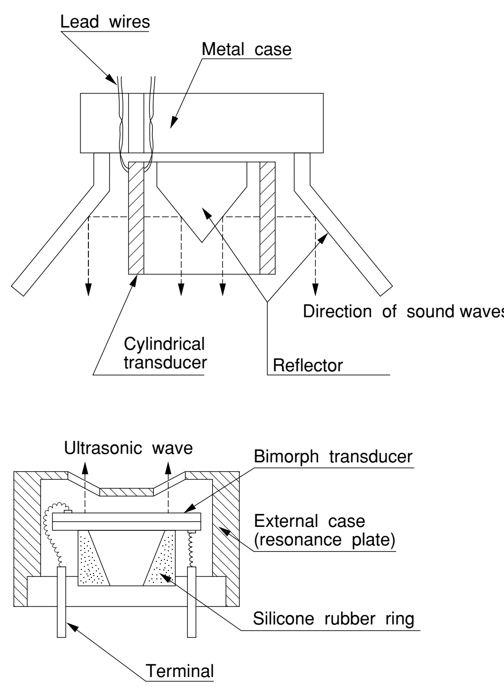


Fig. 2-12. Details of Construction

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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	Disc	Thickness vibration	70 ~ 500	Easy frequency adjustment High mechanical strength	Dimensions and characteristics are determined according to the requirements of specific customers.
b	Square column	Longitudinal vibration	40 ~ 100	Easy frequency adjustment Good electromechanical coupling	
c	Cylinder	Thickness vibration	100 ~ 500	Adjustment of mechanical Q and frequency are easy	
		Diameter direction vibration	10 ~ 200		
d	Langevin	Longitudinal vibration	20 ~ 100	Low frequency can be obtained at low impedance	

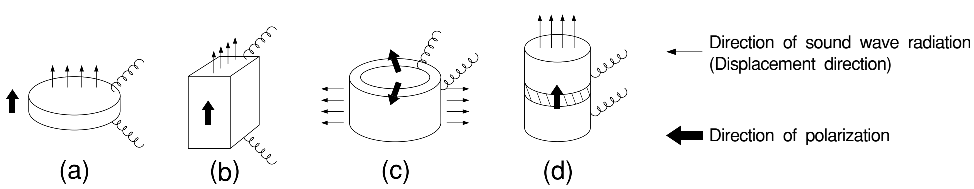

Fig. 2-13

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	Excellent stability at high output levels
N-21	0.38	1800	75	300	Low Qm and high sensitivity

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Precautions

⚠

- The names of the products and the specifications in this catalog are subject to change without notice for the sake of improvement. The manufacturer also reserves the right to discontinue any of these products. At the time of delivery, please ask for specification sheets to check the contents before use.
- Material selection, installation and activation of piezoelectric ceramics should be decided upon by users according to the application. For proper evaluation and decision, products should be tested repeatedly in both realistic and abnormal operating conditions.
- The manufacturer's warranty will not cover any disadvantage or damage caused by improper use of the products, deviating from the characteristics, specifications, or conditions for use described in this catalog.
- Please be advised that the manufacturer accepts no responsibility for any infraction on third party patents or industrial copyrights by users of the manufacturer's products. The manufacturer is responsible only when such infractions are attributable to the structural design of the product and its manufacturing process.
- No part of this document may be reproduced without written permission from the manufacturer.
- Export Control

  For customers outside Japan

  NEC-TOKIN products should not be used or sold for use in the development, production, stockpiling or utilization of any conventional weapons or mass-destructive weapons (nuclear weapons, chemical or biological weapons, or missiles), or any other weapons.

  For customers in Japan

  For products which are controlled items subject to the' Foreign Exchange and Foreign Trade Law' of Japan, the export license specified by the law is required for export.
- When ordering NEPEC Piezoelectric Materials
  Specify the following items when placing an order with NEC TOKIN for NEPEC :
  1) Shape (disc, column, cylinder, square plate, sphere, or bimorph).
  2) Desired material and application.
  3) Dimensions.
  4) Vibration mode and resonant frequency used.
  5) Whether special surface treatment is required, and if so, what type.
  6) S, P, or other designated terminal.
- When ordering transducers or other finished products
  Specify model name and number when placing an order for transducer products such as molded transducers for underwater use. Also note any special requirements.
- This catalog is current as of March 2010.

⚠

●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.
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