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# PRELIMINARY DATA ON NEW LOW LOSS PIEZOELECTRIC CERAMIC

## INTRODUCTION

PZT-4* has been widely used as the active material in high power acoustic radiating transducers. It has been recommended for this application because of its resistance to depoling under conditions of both high electric drive and severe mechanical stress. Furthermore, the dielectric losses remain at low levels even with moderately high electric fields.

However, recent investigations by Berlincourt and Krueger show that dielectric losses are somewhat greater at high fields while under the influence of high static stresses. It is also known that dielectric permittivity increases substantially with drive level as do mechanical losses. 1 For low Q transducers, this increase in mechanical loss should not be a problem.

The development of a so-called super type PZT-4 in which the above limitations are not present or at least minimized seemed to be highly desirable. As a result of work done at Electronic Research Division of Clevite. such a material — PZT-8 — has indeed been developed.

## PRELIMINARY DATA

Preliminary studies of suitable test samples of this material have yielded some rather interesting results. Some of these have already been discussed by Berlincourt. In addition to this, the following data will now be presented:

a. Low signal parameters.
b. Aging data.
c. Dielectric permittivity as a function of electric field at 25° C.
d. Dielectric loss as a function of electric field at 25° C.
e. Temperature dependence of some parameters over the range 0 to 100 °C.

Table I lists some of the more important room temperature low signal properties. Obviously, many other elastic, piezoelectric, and dielectric constants are required to fully define the material. However, these data are not yet available. As a matter of fact, the data that is presented should be considered as tentative since production experience is lacking. Investigations have been under way and will continue in search of optimum processing techniques and thus it is anticipated that the values of most of the properties listed will eventually be revised. These changes will probably not be very marked, however.

**TABLE I**

**PRELIMINARY LOW SIGNAL PROPERTIES OF PZT-8 at 25°C**

| | |
|---|---|
| $k_{33}$ | 0.60 |
| $k_{31}$ | 0.295 |
| $k_p$ | 0.50 |
| $d_{33}$ | $215 \times 10^{-12}$ metres/volt |
| $d_{31}$ | $-95 \times 10^{-12}$ metres/volt |
| $g_{33}$ | $24.5 \times 10^{-3}$ volt-metres/newton |
| $g_{31}$ | $-10.5 \times 10^{-3}$ volt-metres/newton |
| $\varepsilon_{33}^{T}/\varepsilon_o$ | 1000 |
| $Y_{33}^{E}$ | $7.2 \times 10^{10}$ newton/metre$^2$ |
| $Y_{11}^{E}$ | $9.0 \times 10^{10}$ newton/metre$^2$ |
| $\rho$ | $7.65 \times 10^{3}$ kg/metre$^3$ |
| $Q_m$ | 1000 |
| Curie T | 300°C |

These properties are quite similar to those exhibited by PZT-4 although marginal differences do exist. One of the significant differences between the two materials is substantial increase in Mechanical Q with PZT-8. Then, too, as will be shown later, the dielectric loss at high fields is considerably lower with PZT-8.

Table II shows aging of coupling, dielectric permittivity and frequency constant. These rates are based on limited data for a period of over two decades. The aging of dielectric permittivity and frequency are less severe than for PZT-4 while coupling appears to age at a somewhat greater rate.

**TABLE II**
**PRELIMINARY AGING RATES — PZT-8**

| | |
|---|---|
| $\Delta k_p$ / Time Decade | Less than -3. 0 % |
| $\Delta \varepsilon^{T}_{33}$ / Time Decade | Less than -3. 5 % |
| $\Delta$ Freq. Constant / Time Decade | Less than +1.0 % |

Figures 1 and 2 show the behaviour of dielectric permittivity and loss factor with electric drive at room temperature. This data was taken at zero bias stress and is compared with data taken on PZT-4, The difference is quite marked. Don Berlincourt has already shown similar data including the influence of large bias stresses.

Finally, Figure 3 is included to show typical behaviour of some parameters with temperature over the range 0 to 100 C. There is similarity with PZT-4 except that the dielectric permittivity increases more rapidly at temperatures above 75° C with PZT-8. In view of a somewhat reduced Curie Temperature, this is not surprising. Mechanical Q of PZT-8 is not as stable with temperature as is that of PZT-4, but the variation is still not too severe over this range.

**CONCLUSION**

As indicated earlier, more thorough investigations are planned at both the Electronic Research and Piezoelectric Divisions of Clevite to more adequately describe this material. And certainly a reasonable amount of production experience will be required to allow for a complete set of specifications. However, the studies to date indicate that the use of PZT-8 for applications requiring high electric drive should make possible transducer designs of improved performance.

Fig. 1
%age increase in $\varepsilon^T_{33}$ vs Field @ 25°C

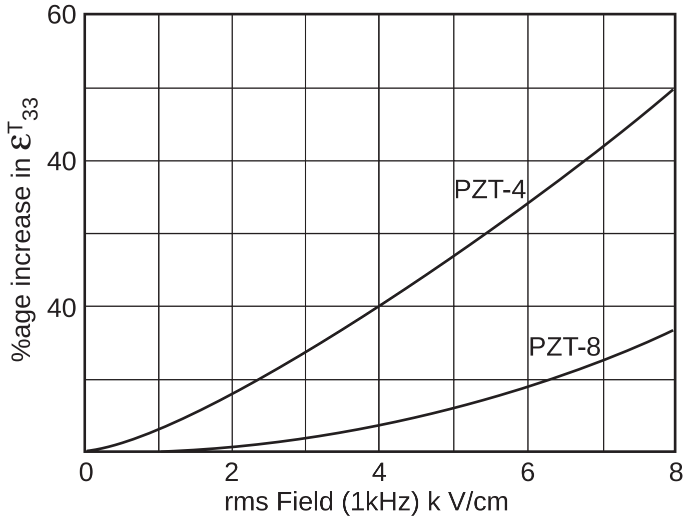


Fig. 2
tan ∂ vs Field (@25°C)

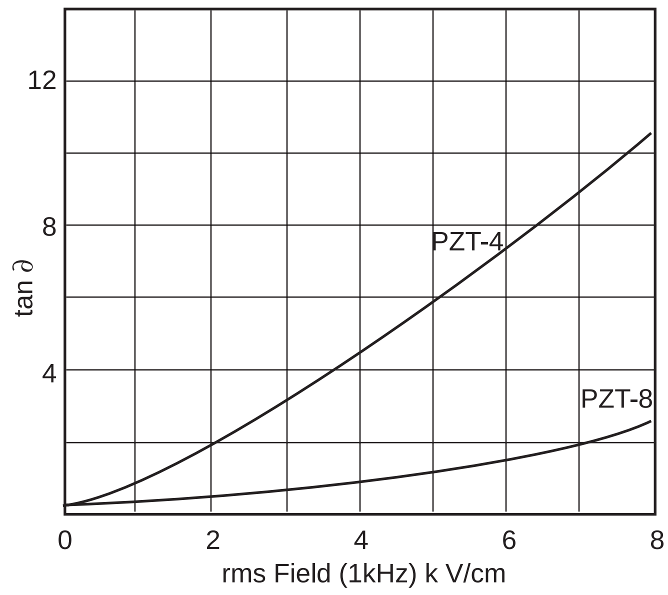


Fig. 3
Temperature Dependance, PZT-8
(Preliminary data – unstabilized)