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# DESIGN OF BENDER TRANSDUCERS AND THEIR RELEVANCE TO LIGHTWEIGHT DESIGN

BY W. F. CRASTER

Compromise between mechanical and physical constraints is most important in Electro-acoustic Transducer design. These mechanical constraints have to be created to prevent power/weight or power/space becoming too low. To establish our lightweight designs various transducer types had to be tested; these included Tonpiltz, Ring, and Bender transducers.

"Figures of merit" for transducer systems are difficult to define, however it is convenient to use watts/lbs.

An Electro-acoustic Transducer converts energy in terms of voltage and current into force and velocity and they can be designed using the principles of :-

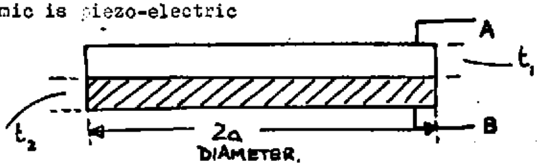
(i) Explosions
or (ii) Electro-magnetics
or (iii) Hydroacoustics
and (iv) Piezo-electrics

R.S. Woollett provides a paper which summerises the advantages of (i), (ii) and (iii). We are concerned with piezo-electric benders and how they can be fitted into the above category (iv) which is also occupied by the Tonpiltz transducer.

Tonpiltz or piston type transducers fitted into medium power 30 watt systems have been replaced by bending plate transducers with 50% savings in weight and space. This saving depends upon frequency, pistons having a design advantage at frequencies <u>above</u> 30 KHz. The lower frequency limit of 600 c/s for Bender design is fixed by restraints of ceramic diameter and thickness.

## The Bender Concept

Benders can be made to various mechanical configurations and we shall restrict** this survey to the metal ceramic sandwich where the ceramic is piezo-electric

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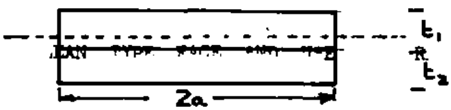
We have produced systems with a measurable degree of shear but it is <u>difficult</u> to produce $\lambda/2$ benders at 10 KHz without resorting to techniques outlined later.

The formulae giving the electrical and mechanical breakdown of these "Discs" give a first order approximation to the transducers' power performance.

Power performance is further influenced by

(i) The method employed in cementing together the elements of metal and ceramic.

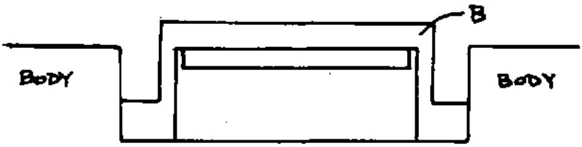
(ii) The position of the "neutral axis".




(iii) The adhesion of the electrode silvering to the ceramic element.

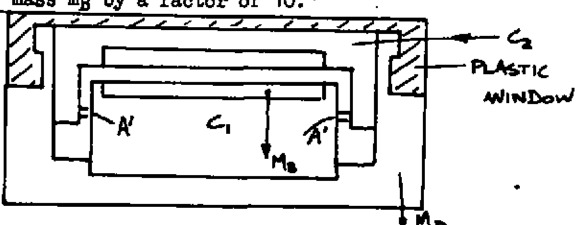
and (iv) Time for which the element can be driven at full power - we usually exceed $10^8$ cycles to establish whether this is the failure mechanism in any particular design.

This latter test employed in (iv) measures the compound effects of (i), (ii) and (iii). We have found that resin glues do not behave well during these fatigue tests - hence the elimination of all epoxy resins from practical systems. (Perhaps due to their temperature fatigue sensitivity and low comparative shear strength).




The element B is fixed into a body by soldering, this produces a "lossless" transducer as long as the body is rigid. Flexural rigidity of the body must be high since low rigidity produces high Q's in water and low efficiencies. A reduction of the resonant frequency $f_1$ occurs if the wrong body design is employed.

We assume that the dynamic mass of the body $M_D$ must exceed the bender mass $M_B$ by a factor of 10.




Our bender is now within a rigid structure and should be exhibiting a resonant frequency $f_1$ or $f_2$ dependent upon the degree of shear. We can build in hydrostatic equalisation and use it to an acoustic advantage.

Hydrostatic pressure acts upon the plastic window and is transmitted to the case. The pressure does not influence the position of the bender since oil can pass through the low pass filter holes A' to the cavity $C_1$. This cavity $C_1$ has a stiffness $K_c$ which is a function of its length l and diameter a

$$K_c = 2.58 \times 10^9 \frac{a^2}{l} \text{ newtons/meter}$$

If $K_D$ is the stiffness of the bender and we assume that the $C_1$ cavity at $f_1$ is stiffness controlled then

$$\frac{K_c}{K_D}$$

becomes another design tool.

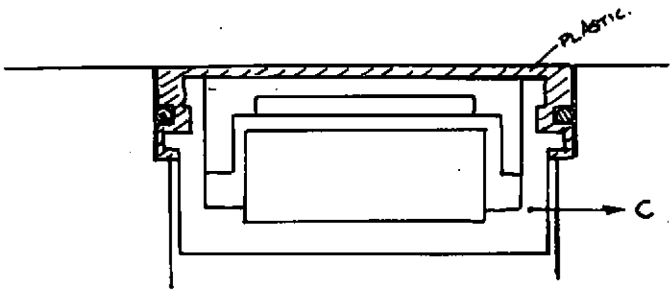
When $\frac{K_c}{K_D} \triangleq 1$ modifications can be made to $f_1$.

This modification tends to increase the lower and upper limits of bender system operation, creation of 30 KHz transducers now becomes possible.

Silicon oil can be mixed with other fluids to make variable compressibility oils. The use of such an oil enables 15% frequency tuning to be built into <u>some</u> of the M.S.82 designs. It is then feasible to frequency tune transducers by using these fluids.

The cavity $C_2$ exists in some of our present M.S.82 transducers to promote a broader pressure response and a lower frequency drop when the transducer is put in water. The normal frequency falls from *$f_{ra}$ to $f_{rw}$ and can be reduced by the use of these horns; this has the effect of raising the upper frequency limit from 30 KHz broader pressure responses, and benefits from horns become apparent at $K_a$ values greater than 1.3.

The use of plastics for windows gives the design a practical protection preventing water from meeting any metal surfaces. Plastics give a low impedance mismatch to the energy being transmitted from the bender to the water. This plastic can create interference effects within the transducer and the following have been tested: Nylon, polypropylene, A.B.S., Perspex, P.T.F.E., and glass filled combinations of some of these. The wrong plastic choice effects the loading and hence the Q and resonant frequency of the finished transducer. Plastics such as nylon and perspex work well and an explanation may be that the former has good water absorption and the latter no macroscopic voids.




* $f_{ra}$ = Resonant frequency in air; $f_{rw}$ = Resonant freq. in water