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END CAP TRANSDUCER DEVELOPMENT

by

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Up to a few years ago magneto-strictive scrolls were used by the Institute for pingers, net-monitors, Swallow float transponders and transceivers on moored systems. The nickel scroll had, however, a number of disadvantages:

1. A low efficiency at 10KHz - usually less than 10%.
2. A variable beam pattern particularly in the axial direction where there is usually a null.
3. Transmitting and receiving sensitivites subject to wide variation between transducers and liable to deteriorate through thermal or mechanical shock.

As the cheap stock of scrolls began to run out it became desirable to have a transducer based on a piezo-electric element that would have higher efficiency, a more uniform beam pattern, be more rugged and not require any underwater connectors. An end-cap transducer had been designed that drove a cylindrical quarter-wavelength matching stub through the thickness of a four inch diameter end-cap, with a four element piezo-electric stack and balancing tail-mass. The tail mass being adjusted to put the mechanical node as close as possible to the 'O' ring face when the transducer was operating into water.

This transducer proved to be highly efficient and capable of working at great depth. However, the mechanical Q was considred to be too high, particularly for the transmission of FM signals, at 25-30. The 3db beam width of 70^{o} was too narrow for most applications. I was given the job of re-designing the transducer to reduce the Q and widen the beam pattern.

The explanation for the high Q became apparent:

1. The small size of the radiating face - about $\frac{1}{3}$ of a wavelength in diameter.
2. The presence of a flexural mode close to 10KHz in the four inch diameter end-cap.
3. Direct radiation and reflection from the end-cap face. (This was also reducing the width of the beam pattern.)

When the transducer was mounted in an adaptor ring and screwed into a six inch diameter tube, the flexural mode dropped to around 7KHz and the Q reduced to 20. Pressure release material on the surface of the end-cap had little effect on the Q but widened the beam-width to 90°. Since neither of these improvements were sufficient and because the pressure-release material prevented the transducer being used at depth, it was decided to increase the radiating area at the possible cost of further reducing the beam-width.

Initially, metallic putty was used to flare out the cylindrical stub to about twice the diameter. This not only reduced the mechanical Q, as the radiation impedance became more real, but also increased the beam-width.

A prototype was drawn up slightly longer than would be required for resonance at 10KHz. The radiating head with its truncated cone approximation to an exponential flare was initially machined as a separate entity from the end-cap so that it might be shortened as necessary by removing material from the cylindrical section. For experimental purposes the separate sections of head-mass, end-cap, PZT4 stack and stainless steel tail mass were bolted together using greased joints. Both the head and tail masses were trimmed to achieve resonance in water at 10KHz while placing the mechanical node at the 'O' ring face.

When the dimensions of the head-mass and the weight of the tail-mass had been finalised several transducers were constructed with the end-cap an integral part, stack and tail-mass properly glued and the central bolt pre-stressed. After further tests several models were made with a six inch diameter end-cap and proved to have a Q in water still lower due to the displacement of the flexural mode to circa 7KHz.

During subsequent use at sea the beam pattern was checked at a greater distance than was possible in a test tank and the signal level was found to be at least equal to that of the nickel scroll at any angle for only a tenth of the transmitter power.

Summary of performance (see figures)

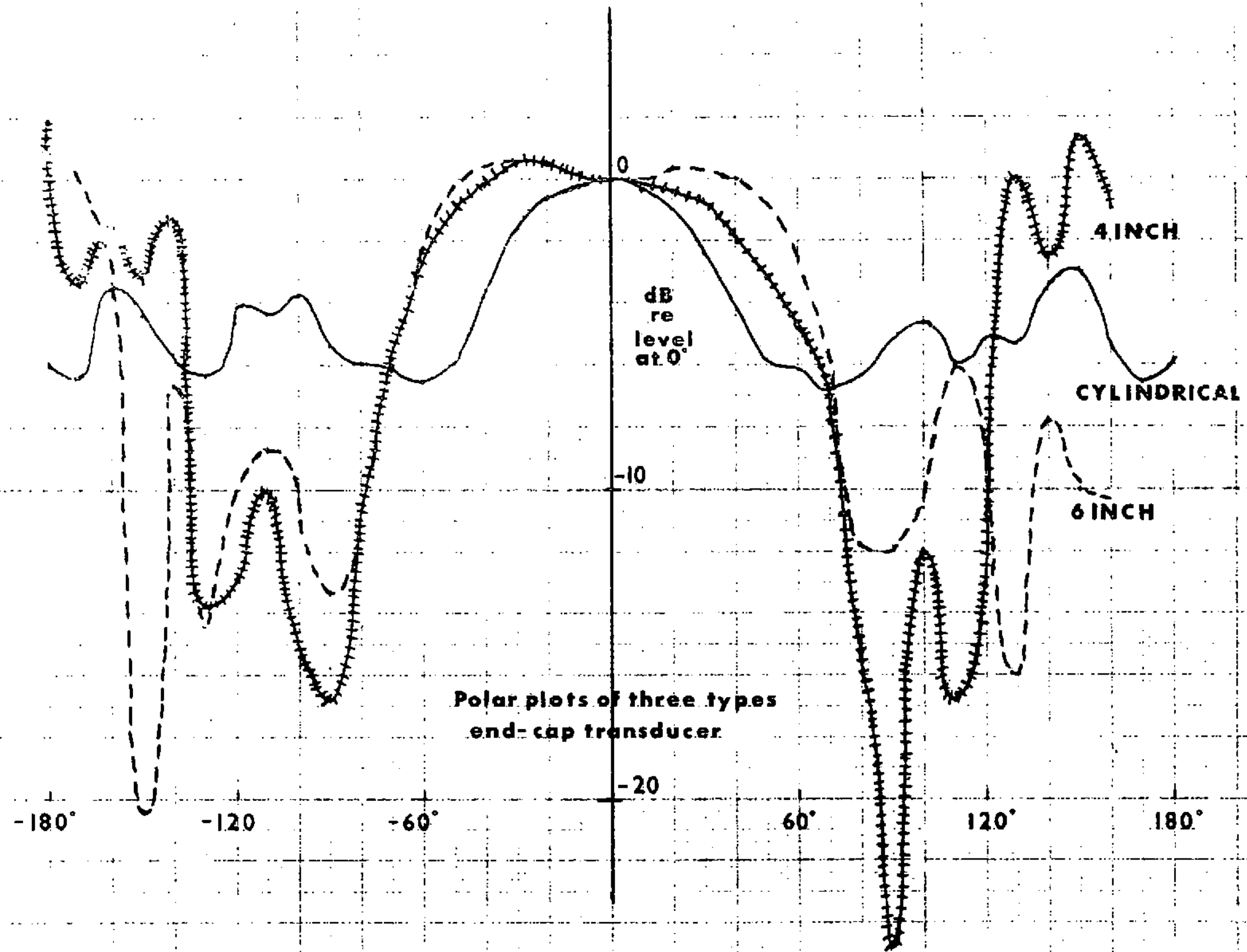
1. Q in air 400-600 for both 4 and 6 inch versions.
   Average over 28 samples = 525.

2. Q in water 4-13, being one or two lower on average for the 6 inch compared with the 4 inch transducer.
   Average over 28 samples = 7.99

3. Beam patterns of 105° and 120° between 3db points for the 4 inch and 6 inch models respectively.

When the assembly of the transducer was sub-contracted out there was a general increase in the Q in air and a reduction in the Q in water as the glueing technique improved and the stack was pre-stressed to a higher level.

To date somewhat over 80 units have been produced and have taken over from nickel scrolls as pingers and transponders which have smaller battery packs, greater acoustic output power and a longer operating life.



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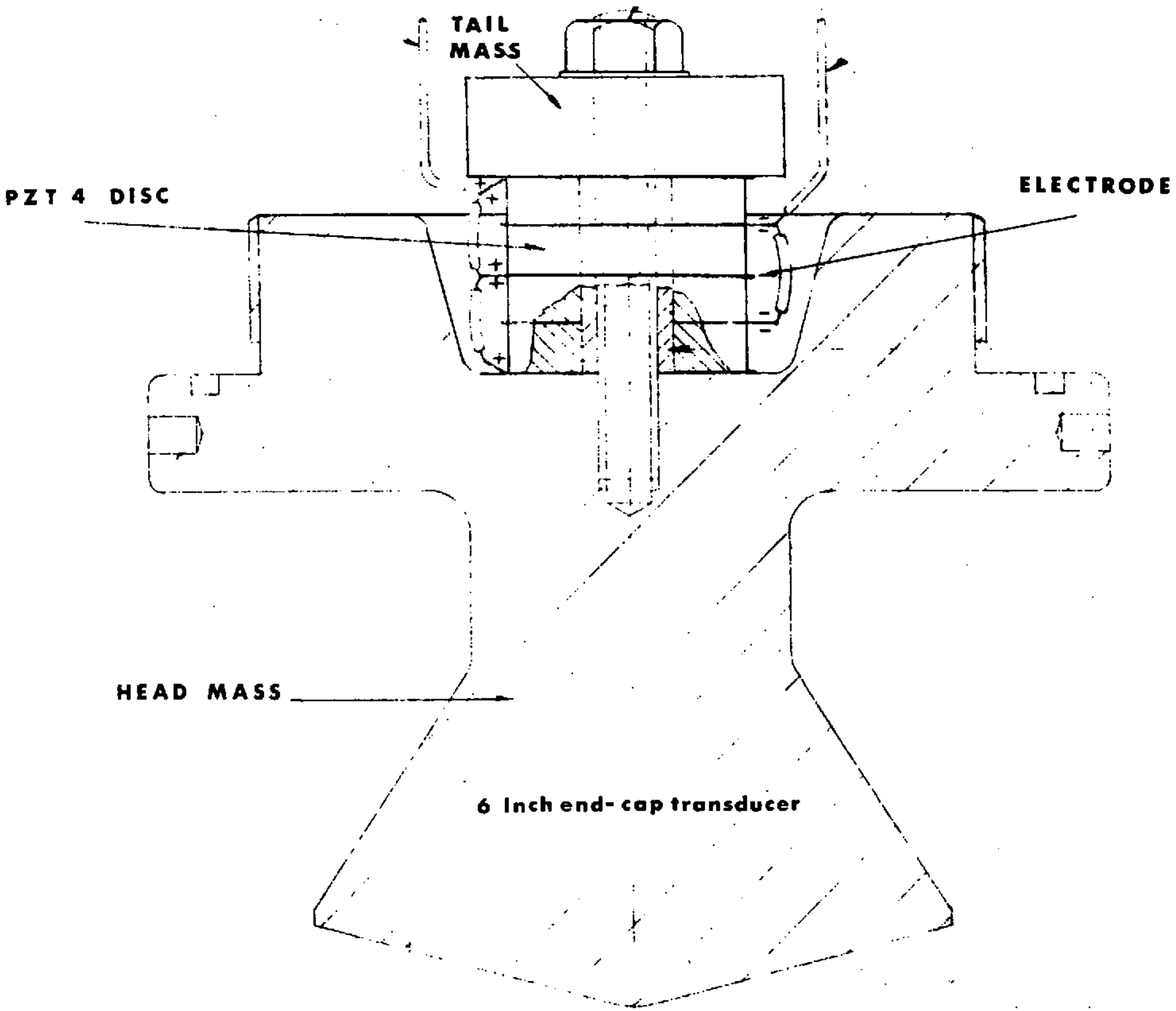
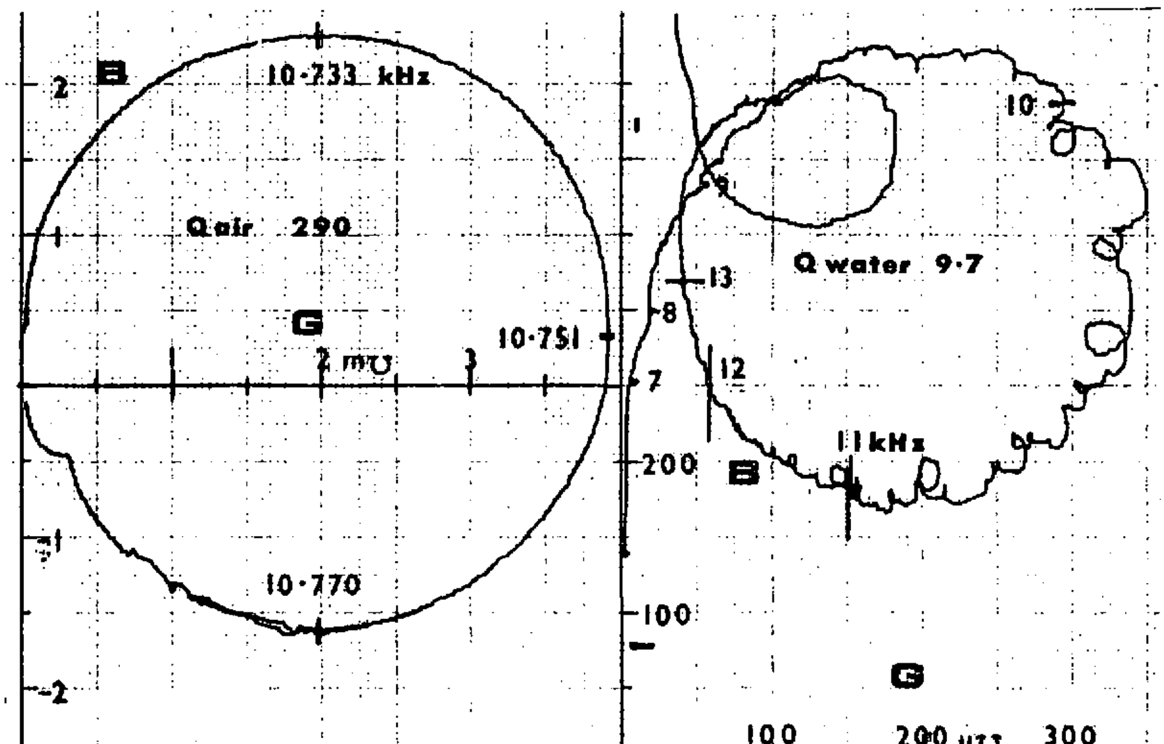
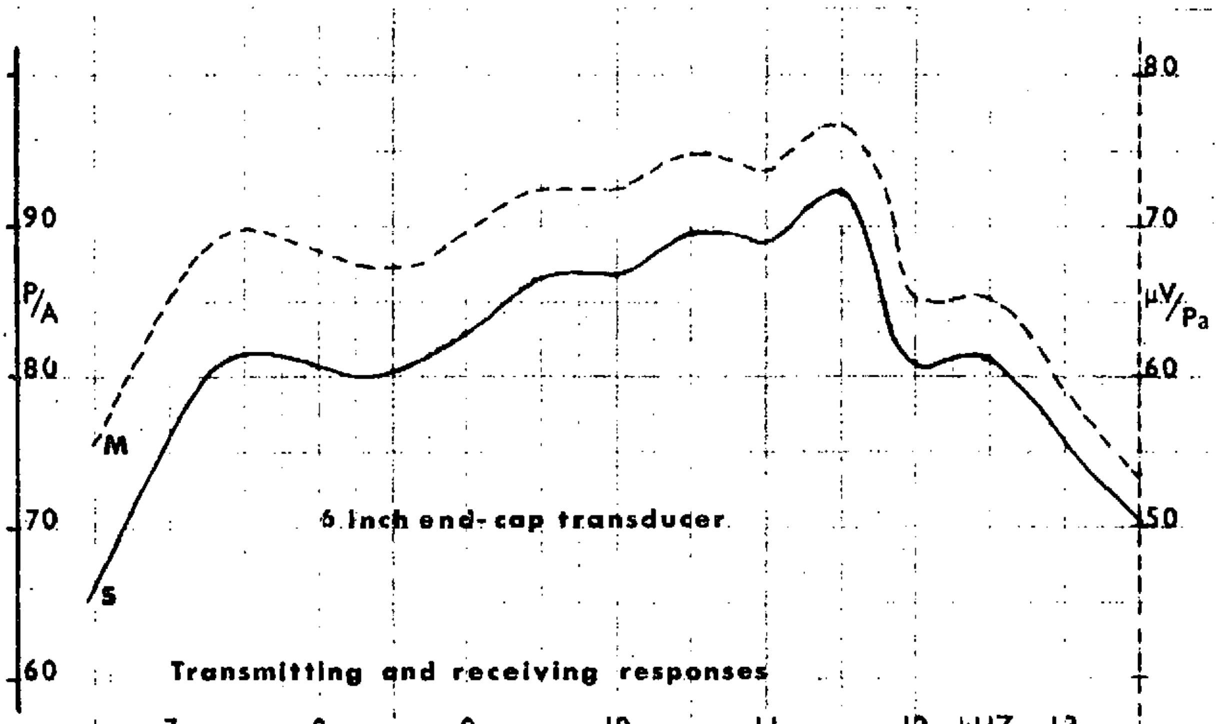
4 INCH
CYLINDRICAL
6 INCH
Polar plots of three types
end-cap transducer



6 Inch end-cap transducer



Admittance circles 6 inch E.C.T.



Transmitting and receiving responses