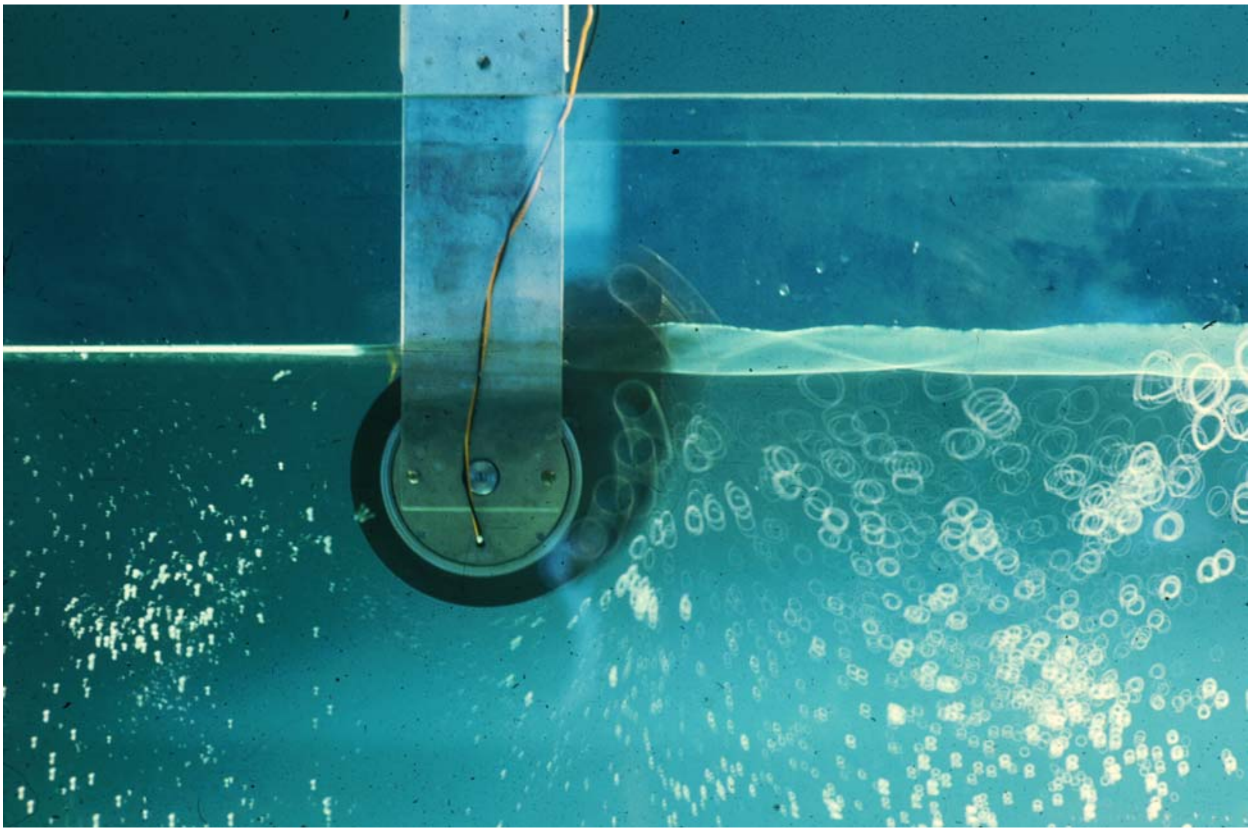
# Edinburgh University Wave Energy Project.

*Duck efficiency*



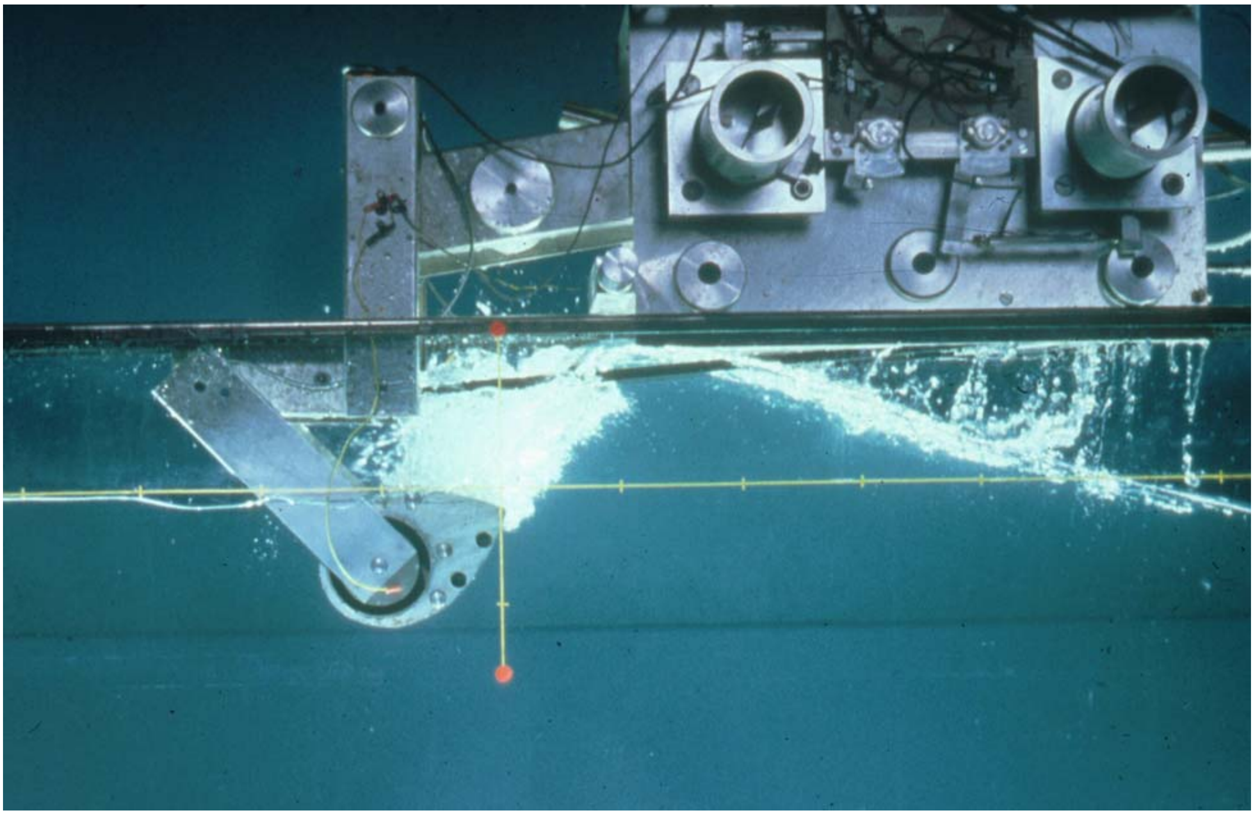
This photograph, taken by Jamie Taylor in 1976, is a one-second exposure of a duck model on a fixed mounting in a narrow tank. The orange and black wires are part of an electromagnetic dynamometer, which is absorbing power. Waves are approaching from the right. Drops of a neutrally buoyant tracer-fluid consisting of a mixture of carbon tetrachloride and xylene with titanium oxide pigment have been injected to show the decaying orbits of wave motion.

The amplitude of the incoming waves can be measured from the thickness of the bright band. Nodes and anti-nodes due to the small amount of reflection are evident. However the thickness of the bright band to the left of the model is largely due to the meniscus, as is confirmed by the very small orbits of tracer fluid in this region. As the energy in a wave is proportional to the square of wave amplitude we can use the photograph to do energy accounting. If reflected and transmitted waves are one-fifth of the amplitude of the input they would have one twenty-fifth, or 4%, of its energy. This means that 96% has gone into the movement of the test model. The dynamometer showed that just over 90% of the power in the full width of the tank had been absorbed by the power take-off, leaving 6% loss through viscous skin friction.

A later model mounting with controlled stiffness and damping in heave and surge allowed us to replicate the behaviour of models on a long, compliant, yielding spine and to make the circular stern of the model behave like the highly efficient Evans cylinder. The movement generated waves that cancelled the longer ones that were escaping below the model and so widened the bandwidth of efficient operation.

# Edinburgh University Wave Energy Project.

*Duck Survival*



This photograph, from 1977, shows the second model mounting used for simulating the behaviour of long spines in a narrow tank and for survival tests. The vertical and horizontal movements of the rig are force-sensitive and can be given separate stiffness, damping and inertia. The electronic control can also allow them to be programmed to yield at a chosen force.

In deep water, long waves travel faster than short ones, with velocity being proportional to the wave period. For the survival tests we used a wave-maker command signal which was a combination of frequencies corresponding to a realistic spectrum but with starting phases chosen with malice aforethought, so that all components coincided at the test point to produce a spectacular plunging breaker. The rig was then moved to allow tests at many positions either side of the nominal break position.

Capsize of the duck and yielding of its support will generate waves astern which reduce the long-term mean mooring forces. Indeed, for some low freeboard models, the mooring forces became negative. The hump on the back of the duck allows it to just recover from capsize.

At full scale the wave shown would have a power of about 600 Megawatts, one hundred times greater than our estimate for the economic power limit for a duck in an offshore Atlantic wave climate. The Edinburgh team believe that, no matter the complexity required, controlled yielding is essential for economics because the model never has to suffer any stresses greater than those associated with the economic power limit.