

Relocation of a Multidirectional Mixed Wave Spectrum Test-Tank with Modifications for Reduced Area and Minimum Cross-wave Errors.

GR/R64438/01

IGR report to EPSRC

May 2003

S H Salter, Engineering and Electronics, Mayfield Road, University of Edinburgh, EH9 3JL.
tel 0131 650 5703. fax 0131 650 5702. S.Salter@ed.ac.uk

Background.

Research into wave energy makes particular demands on the repeatability and realism of test tanks. The principles of energy absorption needed for the wave energy devices can also be applied to wave makers. This allows them to reduce the errors caused by reflections and cross waves. Continuous experiments can be carried out with very high repeatability. In 1977 the Edinburgh wave energy team built a tank with 89 wave makers using force-based absorption. It was the first tank which had accurate control of directional sea conditions over a wide frontage. Its has led to many descendant tanks, sold round the world by a spin-off company Edinburgh Designs. Its unusually large width, five times its length in the wave direction, was chosen because of the need to test models of long compliant spines. This had the result that models in the centre of the tank were exposed to a wide angular spread of waves and also that only a small fraction of the perimeter was reflective. This avoided the problems suffered by many tanks with opposite parallel walls which encourage the growth of cross waves giving poor repeatability and long settling times.

The land on which the tank was built was leased to the wave energy group with a clause which required its return after five years. After 23 years the clause was invoked to allow the construction of a large new laboratory for research into extreme conditions, funded as part of a JIF bid to the Wellcome Foundation. The only space available for a replacement tank was much smaller but we wanted to retain, or even increase, the wide angular spread for short models.

The new design.

The plan of the tank is shown in figure 1. A subset (48 of the 89) of the original wavemakers are arranged in an arc with a centre outside the laboratory but under a work platform in the form of an arc of smaller radius with a centre just inside the wall. This will allow the future installation of a swinging boom for the movement of wave gauge arrays and towed models.

The arc avoided the discontinuity of the L-shape plan of the original proposal which would have required some awkward orchestration software. We were however concerned about the possibility of sloshing in the wave maker gussets caused when adjacent wave makers move slightly towards one another. We prepared contingency designs for slosh dampers in the form of skeleton foam pads with interlocking teeth which could be fitted to the front to the wave makers.

Clearing several large concrete foundation blocks from space in a disused civil engineering laboratory required an extremely noisy pneumatic drill and had to be done over the New Year holiday to avoid annoyance to nearby teaching areas. It was also necessary to fill some under-floor sumps.

Construction

The old 1977 wavemakers were mounted in sets of eight on steel fabrications looking rather like upright pianos made by Cutting Edge of Glasgow who were able to fold the fronts into the sides of a polygon with the correct radius from the tank centre. The low-inertia, printed-armature motors had been bought as scrap in 1977, many with armatures which had had to be re-glued to the spindles. We tested them carefully, replaced a few brushes and reinstalled them with their original electronic amplifiers and analogue absorption control boards, all of which have survived better than any of the commercial electronic equipment we bought at the time.

The first tank lining had been made from Terylene felt rolls and had given us endless trouble with leaks at the seams until it was replaced by a continuous, hand-laid glass-fibre polyester resin lining fitted by Colvic. We approached them again but they company had moved out of the lining business. We therefore issued a contract to John Metcalfe ltd who can apply a sprayed lining which was much cheaper than hand laying. It is tough enough for people to walk on in hard boots. It has proved completely leak proof but seems more susceptible to biological growth than did the glass-fibre material.

Absorbing wave makers which use a force input to the control loop must not have water behind them and so water is retained by a flexible fabric wall made from polyurethane-faced nylon, like the material used for anoraks, with gussets between each wave maker. The 1977 gussets had been glued with tetra-hydra-furan. This can dissolve polyurethane and make it behave like an adhesive tape for about thirty seconds. Despite its delightful smell is now known to be an dangerous carcinogen. When gussets started to fail after 17 years use (with several failures in the same week) we replaced them with an ultrasonically welded material supplied by Flexitec Structures who now make all fabric walls for Edinburgh Designs. We went back to them for the new tank.

Switching on

Despite our theoretical confidence in the predictions of Huyghens that an arc of wave makers can produce a straight wave front, it was still a profound relief when everything worked at the first attempt. It had taken only four hours to modify the software which had been written for a straight line of wave makers. We also found that the convergence of energy from the arc could produce an extremely satisfying even if highly improbably freak wave as shown in figure 2. Sloshing in the wave maker gussets does occur if we generate very steep, very short wave waves but did not turn out to be a problem for spectra with realistic amplitudes of the high frequency components. With confidence established in the arc we felt justified in ordering a crane from Herbert Morrison.

Beaches

Natural beaches with shallow slopes dissipate energy by forcing the wave to break in water depths of the order of a wave height. But if a shallow slope is used from the full depth of the tank, the size of the building becomes extreme. Many laboratory beaches are therefore built as arcs or parabolas with the dissipation only at the very surface.

Wave energy research makes high demands on beach quality because of the need to make repeatable, long-term measurements of the power input. Furthermore measurement of hydrodynamic damping and inertia coefficients made by shaking the models in calm water are affected by reflections of sub-millimetre waves which are too small to induce proper wave breaking.

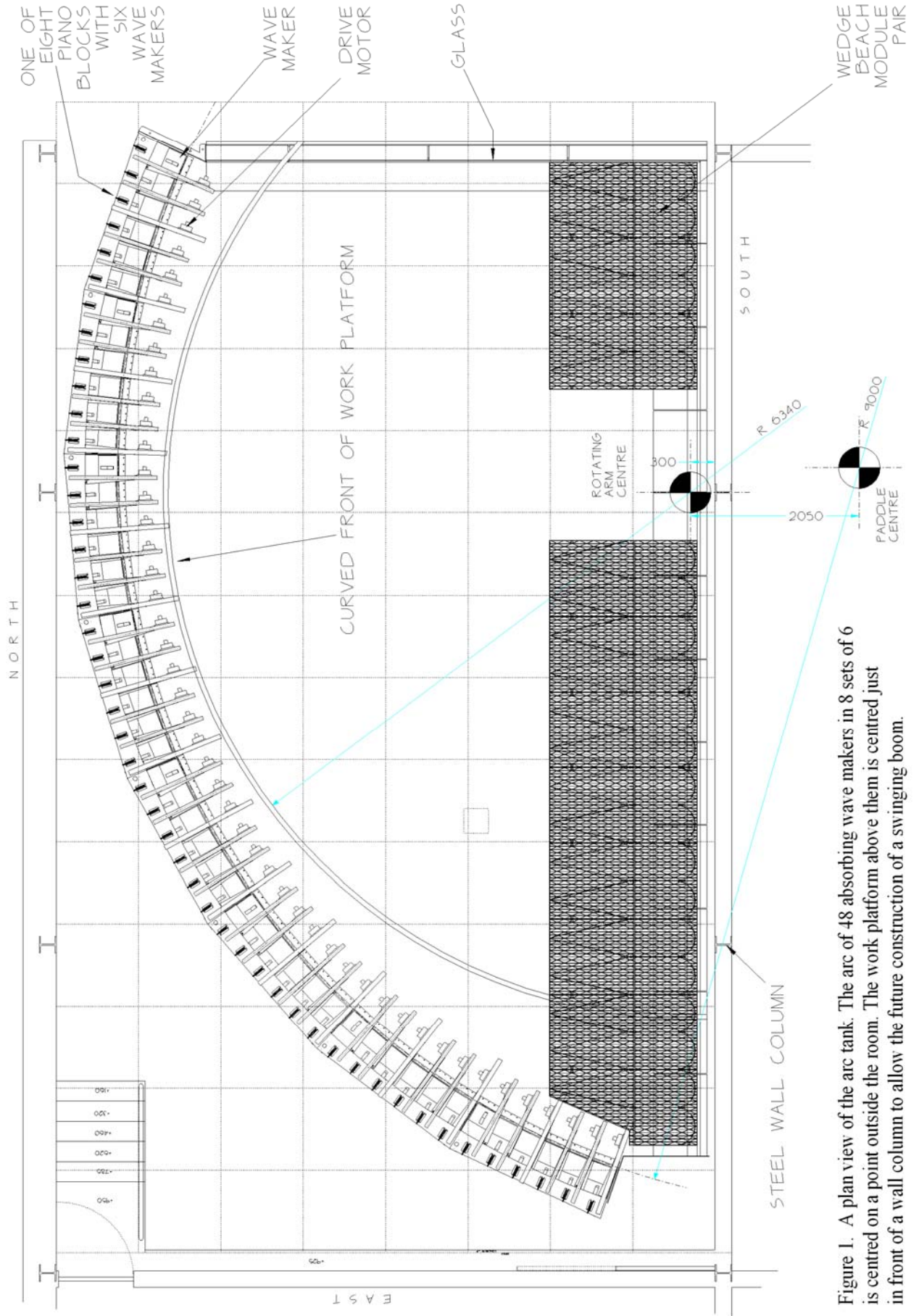


Figure 1. A plan view of the arc tank. The arc of 48 absorbing wave makers in 8 sets of 6 is centred on a point outside the room. The work platform above them is centred just in front of a wall column to allow the future construction of a swinging boom.

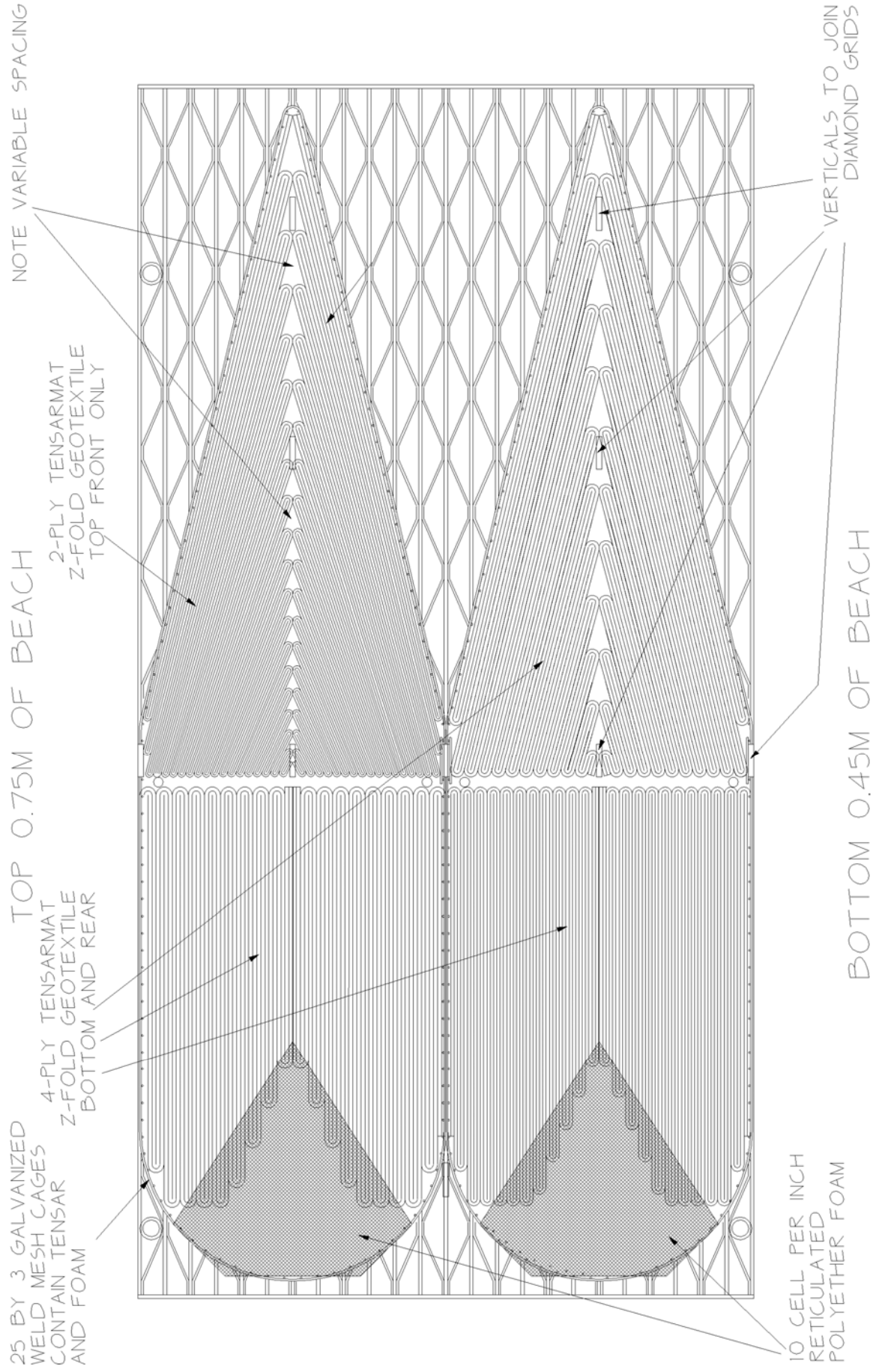


Figure 3. The packing density of the geotextile Z-folds is increased with distance along the wedge.



Figure 2. The generation of a freak wave is a good way to check the tank transfer function.

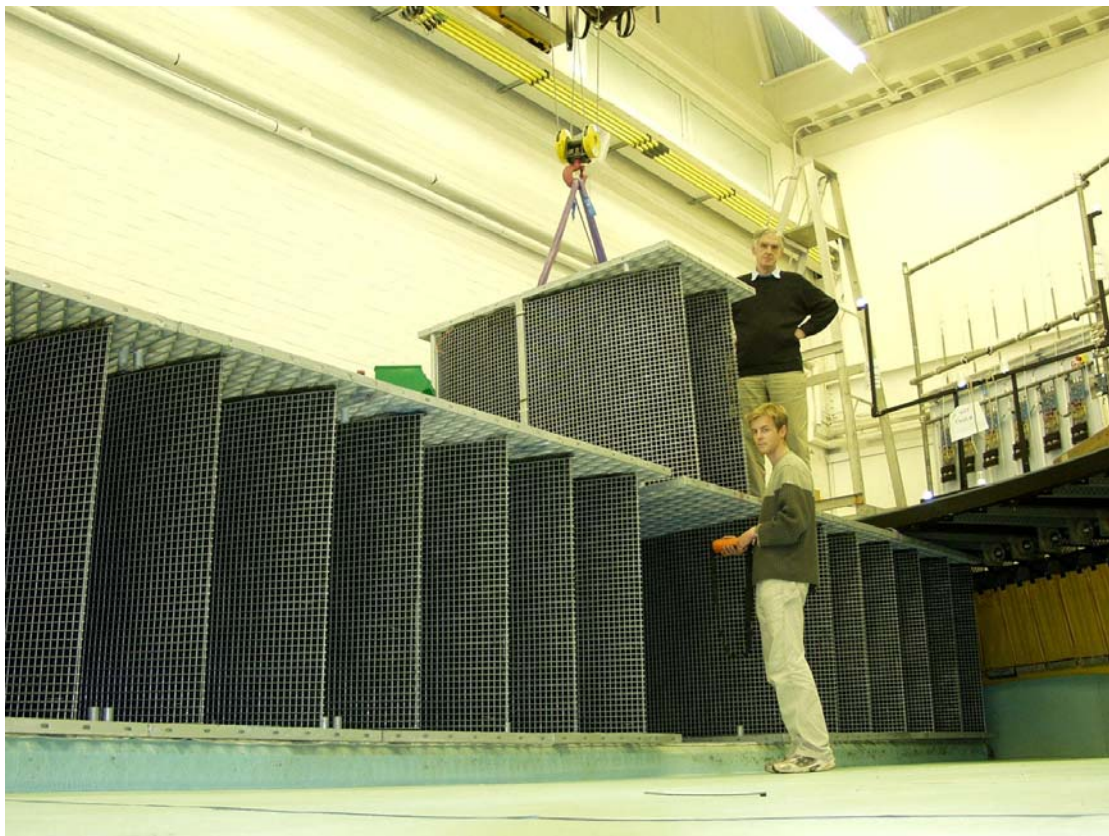


Figure 4. Putting the wedge beach modules into position.

In 1976 the Edinburgh wave team experimented with vertical wedge cages like a slice of cake containing 'Expamet', an expanded aluminium foil. This gives millions of sharp edges but very little bulk. The first beach in a narrow tank had spectacular performance with only 2% amplitude reflection for waves of medium steepness. This idea was used for the 1977 tank with cages made from Weldmesh built underneath a chipboard and scaffolding work platform. After many years of use some of the Expamet was damaged and it was not easy to get uniform reflective properties with replacement sheets. Galvanising was coming off the Weldmesh. Finally the old beaches had been designed for a 5 foot tank walls and the replacements were available only 1.5 metres. With confidence in arc tanks established we decided to replace them.

The new design retains the wedge idea but the absorbing material is a mixture of Polyether skeleton foam and a geo-textile known as Tensar. The wedges fit between two platforms of Diamond grid work staging joined together with welded steel verticals which have minimal obstruction in the dominant wave direction.

The ideal beach material would have forces that are proportional to the first power of water velocity and would ideally present the same impedance to waves as unobstructed water. Reynolds number for the smallest, long period waves shows that we are in the viscous flow regime but the larger waves have forces which rise with velocity squared. The best compromise is achieved if the density of the beach can be progressively increased with depth and with distance down wave. With an increase in wedge thickness this makes the inevitable rise in impedance be gradual.

Geo-textile is available in single and double ply. Long strips can be folded in zig-zag layers which become more tightly packed at the back of a triangular cage. The material can be packed in three vertical layers with double ply at the bottom of the tank and a skeleton foam wedge at the very back. Figure 3 shows the zigzag packing. Figure 4 shows a module of the new beach being lowered into place.

Conclusions.

Having wave makers in an arc works well for getting a wide angular spread and will be offered by Edinburgh Designs. One day, no tanks will be built with opposite parallel reflecting walls.

Gusset sloshing occurs but at an acceptable level and will not be present with the hollow-inner wave maker design being considered for the 360 degree combined wave/current tank.

Geo-textile arranged in variably-spaced Z-folds is a good way to make a progressively increasing beach density needed to overcome the transition of from first-order to square-law fluid forces.

Cost estimates were accurate but things took much longer than for the first tank. Having one's laboratory forcibly demolished was far more traumatic than we ever expected. The tank is now in use for wave energy work as well as for six small sub-contracts. However it will take a long time to regain the effective operation of the old installation, not because of the major reconstruction but because of the innumerable little things like tools and calibration leads which get broken or lost in the move.

The construction sequence, and soon, some video can be seen at :

<http://www.mech.ed.ac.uk/research/wavepower/new%20tank/curved%20tank%20working.htm>