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Comments Here's the info on the Piezoelectric Sea Power Generator. Feel free to put it in the PES wiki & appreciate feedback.

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Piezoelectric Sea Power Generator

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Background of the Invention

Piezoelectricity is the term for electrical current generated by mechanical stress, or pressure, applied to certain non-conductive solids. The effect was first discovered by the Jacques and Pierre Curie brothers in the 1880s. The Curie brothers applied pressure to common crystalline materials, such as cane sugar, salt, and quartz, and found that electrical charges appeared, and these ***charges were proportional to the stress applied.***

Piezoelectric materials science has evolved from natural crystals, such as quartz, to exotic manufactured piezoceramic materials, which can produce various voltages under stress.

Subsequent developments in the field since then have led to the development of high voltage source devices, sensors, and actuators. Perhaps the most well-known application is the car cigarette lighter and the common doorbell buzzer. But the technology has also been useful in sonar development, ultrasound medical and non-destructive inspection applications, and electronics equipment.

Currently, the latest research revolves around "power harvesting" from vibrations using piezoelectric materials. Power harvesting is the term used to describe the process of acquiring the energy surrounding a system and converting it into usable electrical energy. This research has been sparked for the need for wireless power sources for the new wireless technology (WiFi laptop computers, cell phones, etc.). However, the research has been into mostly low voltage applications. [See Ref 1].

Power harvesting research has delved into piezoelectric applications mainly due to the development of powerful new composite piezoelectric ceramic materials. The lead titanate zirconate group and even newer lead-free ceramic materials seem to show the most promise for future applications over a range of compositions. [See Refs 2 &3].

Summary of the Invention

Mr. Dickson is pioneering ideas of using hydrostatic pressure for power harvesting, and has an earlier invention, the "hydrosphere", which converts hydrostatic pressure to electrical current via pressure differentials and secondary effects. However, "piezoelectric mats" represent a more direct way to convert water (i.e., hydrostatic) pressure into electricity.

Essentially, this patent pending idea consists of embedding shaped (round, square or rectangular) piezoceramics, hereafter referred to as "piezoelectric cells", into sealed, rubber coated mats, which would then be placed on sea or lake beds at great depths. The mats are linked together via electric cable connections, and the embedded piezoceramics cells are also linked in series within the mats, so that the combined effect of all the electricity generated from the vibrating water pressure in the water column directly above the mats is harnessed and transmitted to shore via power cables on the sea or lake bed.

For example, at sea or lake bed depth of 300 meters, the ambient water pressure vibrating in the water column above the sea or lake bed is 444.3 PSI (pounds per square inch), more than sufficient vibrating pressure to generate electricity from piezoceramic materials.

The attached drawings show a typical piezoelectric mat section and then a cross-section of one piezoelectric cell within the mat.

The mathematics behind the piezoelectric effect are well-known and the equations below are the essential ones:

Piezoelectricity is the combined effect of the electrical behavior of the material:

$$D = \epsilon E$$

Where D is the electric displacement, ϵ is permittivity and E is electric field strength, and Hooke's Law:

$$S = sT$$

Where S is strain, s is compliance and T is stress.

These may be combined into so-called *coupled equations*, of which the strain-charge form is:

$$\{S\} = \left[s^E\right]\{T\} + [d_t]\{E\}$$
$$\{D\} = [d]\{T\} + \left[\epsilon^T\right]\{E\}$$

where d represents the piezoelectric constants, and the superscript E indicates a zero, or constant, electric field; the superscript indicates a zero, or constant, stress field; and the subscript t stands for transposition of a matrix.

The strain-charge for a material of the 6mm crystal class (such as a poled piezoelectric ceramic, e.g. PZT) may also be written as

$$\begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{bmatrix} = \begin{bmatrix} s_{11}^E & s_{12}^E & s_{13}^E & 0 & 0 & 0 \\ s_{12}^E & s_{11}^E & s_{13}^E & 0 & 0 & 0 \\ s_{13}^E & s_{13}^E & s_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & s_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{44}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & s_{66}^E = 2\left(s_{11}^E - s_{12}^E\right) \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{bmatrix} + \begin{bmatrix} 0 & 0 & d_{31} \\ 0 & 0 & d_{31} \\ 0 & 0 & d_{33} \\ 0 & d_{15} & 0 \\ d_{15} & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

$$\begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{15} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{bmatrix} + \begin{bmatrix} \epsilon_{11} & 0 & 0 \\ 0 & \epsilon_{11} & 0 \\ 0 & 0 & \epsilon_{33} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

The bending forces generated by converse piezoelectricity are extremely high, of the order of tens of millions of pounds (tens o meganewtons), and usually cannot be constrained. The only reason the force is usually not noticed is because it causes a displacement of the order of one billionth of an inch (a few nanometers).

Although the above equations are the most used form in literature, some comments about the notation are necessary. Generally and E are vectors, that is, Cartesian tensor of rank-1; and ϵ is Cartesian tensor of rank-2. Strain and stress are, in principle, also rank-2 tensors. But conventionally, because strain and stress are all symmetric tensors, the substript of strain and stress can be r labled in the following fashion: $11 \to 1$; $22 \to 2$; $33 \to 3$; $12 \to 4$; $23 \to 5$; $13 \to 6$. (Different conventior may be used by different authors in literature. Say, some use $23 \to 6$; $13 \to 5$ instead.) That is why S and T appear to ha the "vector form" of 6 components. Consequently, s appears to be a 6 by 6 matrix instead of rank-4 tensor.

Thus, Mr. Dickson estimates that a field of piezoelectric mats, two kilometers square, laid down on the sea or lake bed, at 300 meters depth could generate up to 3.56 MW of continuous, non-polluting electrical power, based on the following assumptions: (1) individual piezoelectric cells, measuring 2,500 square centimeters with a power output of .5 watts each, (2) four such cells described above per mat section, measuring 22,500 square centimeters for each mat, and (3) total power output of 3.56 MW, for the two kilometer piezoelectric field (calculations: [(40,000,000,000 sq cm field/22,500)*2Watts]/1,000,000,000=3.56MW output of field).

Environmental Considerations

There might be some adverse environmental impact to deep-dwelling benthic organisms, such as echinoderms (starfish), holothurians (sea cucumbers), worms and mollusks, simply due to the fact that the piezoelectric mats would occupy these creatures' habitats over the field areas. However, the webbed design of the piezoelectric mats minimizes this impact by allowing for hollow spacing between piezoelectric cells, and thus access to the sea or lake bed. No other potentially adverse environmental impact is known.

Cost Considerations

While no cost calculations exist, it is presumed that the cost per KW hour would initially most likely be equivalent to other renewable energy technologies, including solar and wind, and possibly even cheaper over time. This is based on several assumptions: (1) piezoelectric material science is mature, and virtually no R&D would have to be spent on new piezoceramic materials development. There are numerous suitable materials currently available as previously mentioned; (2) the piezoelectric cells and mats, again are constructed from existing materials: rubber and polymers, so no R&D costs there either; (3) the piezoelectric cells and mats are simple in design and uniform in shape, and thus would be cheap and easy to manufacture in large quantities; (4) the main initial cost would be installation. Working in the marine or lake environment is expensive: ships, support submersibles, divers, etc. However, these are one-time costs. Once the mat fields are laid down, the technology is sturdy and reliable enough to require little preventive maintenance. Barring undersea earthquakes, volcanoes, landslides or acts of sabotage, the piezoelectric fields could function over long periods of time with little attention. Proper oceanographic study and location of piezoelectric mat fields could also minimize these threats as well. The best and most economical locations would be flat, geologically stable sections of the oceans' continental shelves or lake beds.

Other Applications

Aside from commercial power applications, piezoelectric mats could also be used by the U.S. Navy and Marines to provide reliable, defensible power sources in remote locations. For example, Navy transport vessels could lay down piezoelectric mat fields distantly offshore from a Marine amphibious assault location, providing continuous, hidden electrical power supplies in support of the Marine base camp and infrastructure ashore, as well as augmented electrical power for Naval ships in the combat area.

Piezoelectric mats could also be molded around shaped, large weighted objects, attached to insulated cables, and then lowered to the proper depth in the ocean and trailed from ships, including pleasure craft, to provide a continuous electrical power source.

Ref (1):

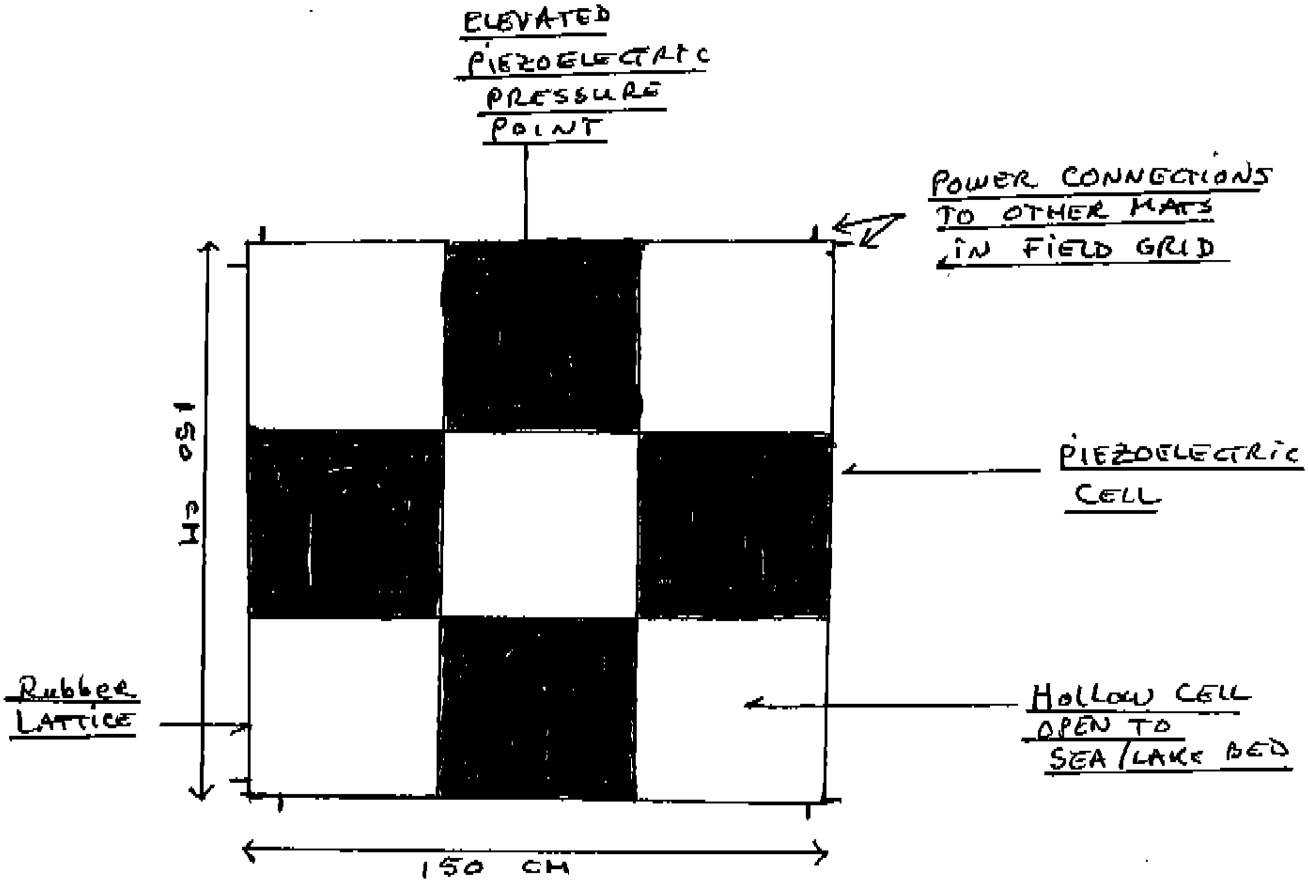
A Review of Power Harvesting from Vibration Using Piezoelectric Materials by H.A. Sodano, D.J. Inman and G. Park, Shock and Vibration Digest, Vol. 36, No.3, pgs 197-206 (2004).

Ref (2):

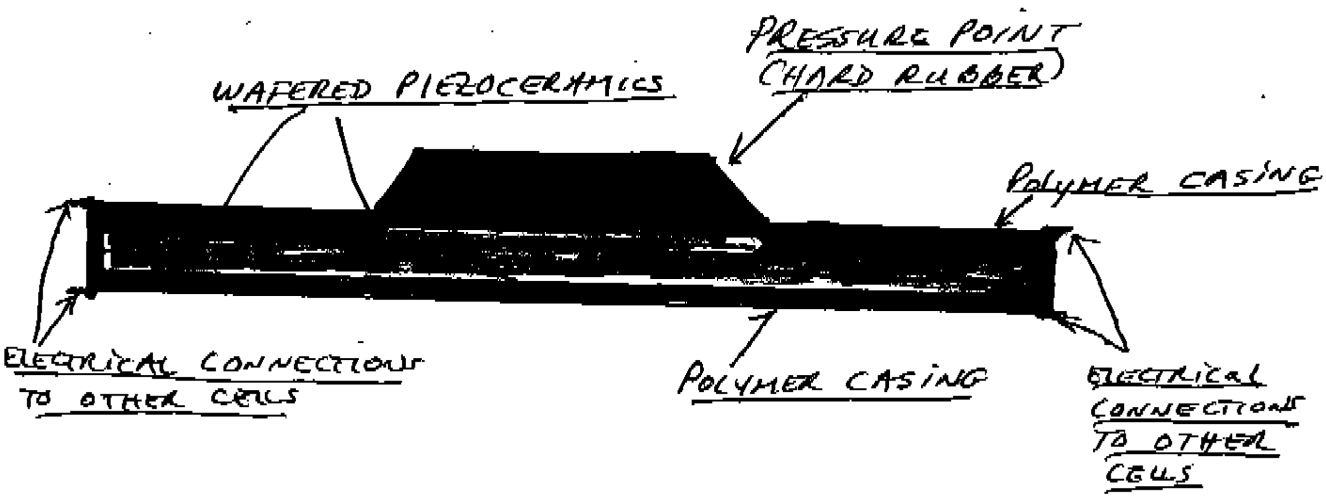
Piezoelectric Ceramics by Hans Jaffe, Journal of the American Ceramic Society, Volume 41:11, Page 494, November, 1958.

Ref (3):

Proccssing and Piezoelectric Properties of Lead-Free (K,Na) (Nb,Ta) 03 Ceramics, Journal of the American Ceramic Society, Volume 88:5, pages 1190-1196 (2005)



ATCH 1 - PIEZOELECTRIC SEA MAT
(TOP DOWN VIEW)



ATCH2 - PIEZOELECTRIC CELL
(SIDE VIEW)
(50 X 50 CM)