

Aug. 9, 1966

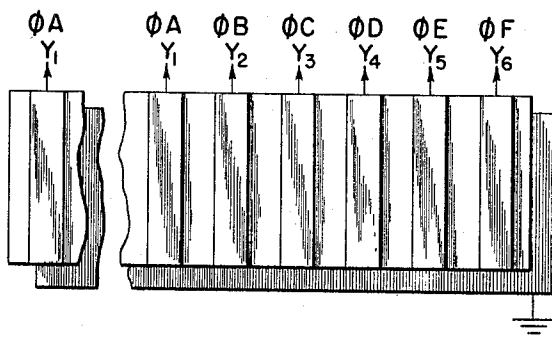
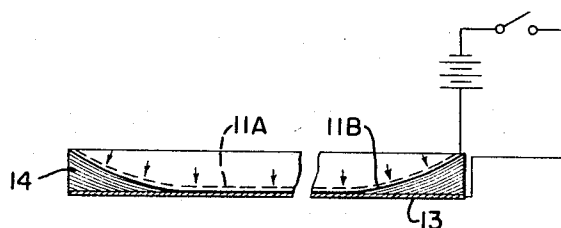
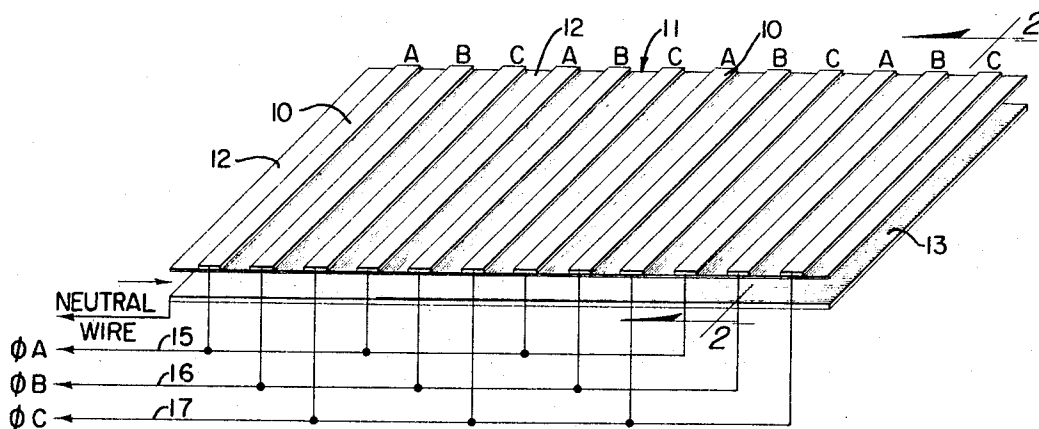
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3,264,998

TRAVELING WAVE HIGH FREQUENCY VACUUM PUMP

Filed Sept. 20, 1963

4 Sheets-Sheet 1



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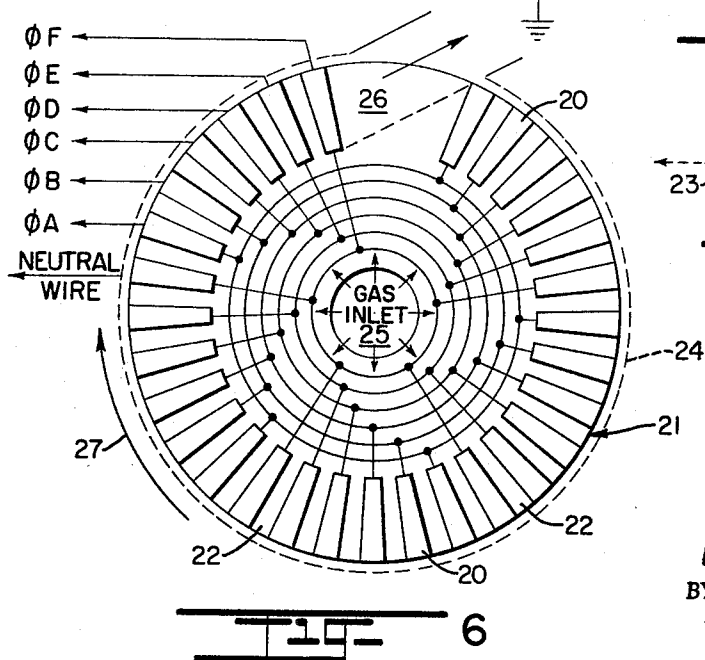
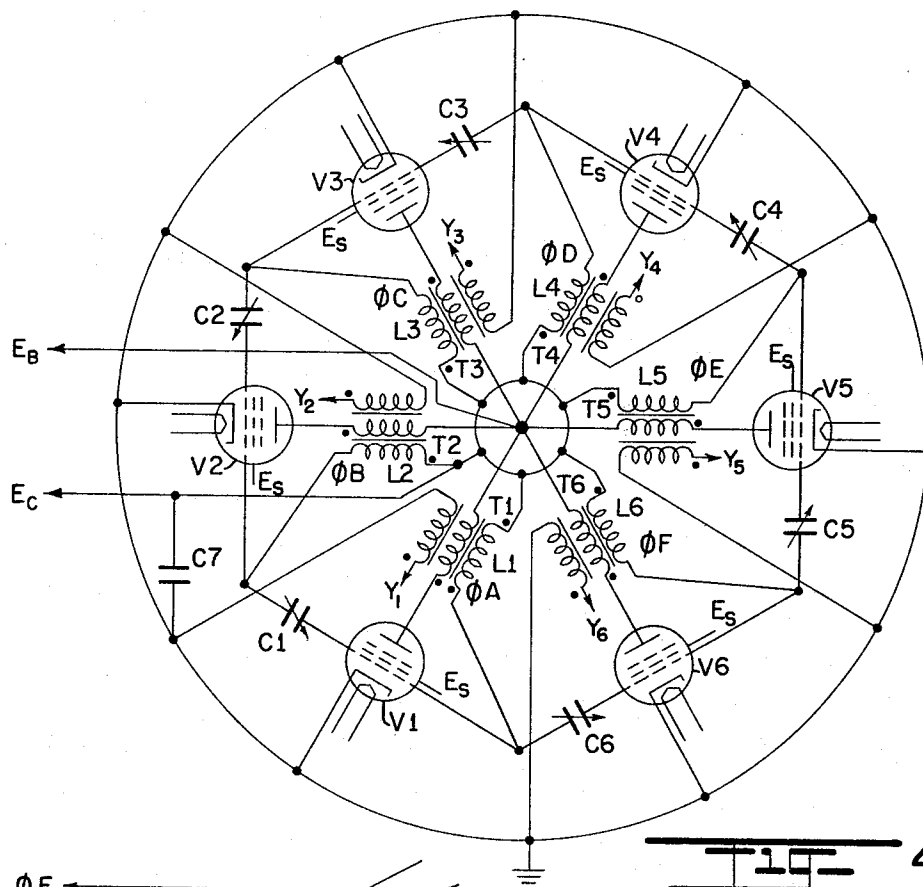
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TRAVELING WAVE HIGH FREQUENCY VACUUM PUMP

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4 Sheets-Sheet 3



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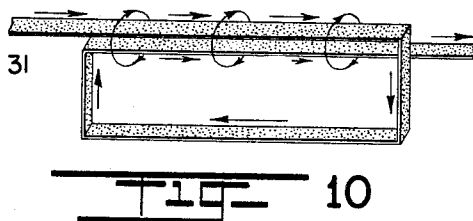
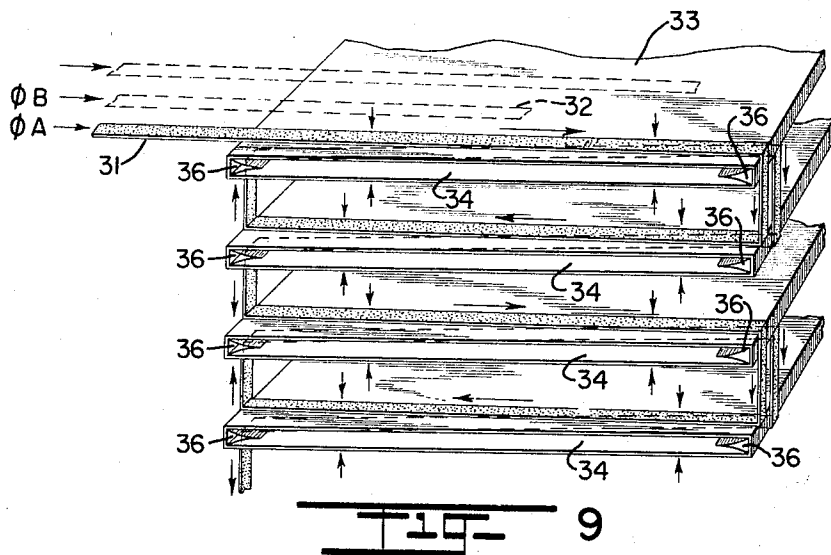
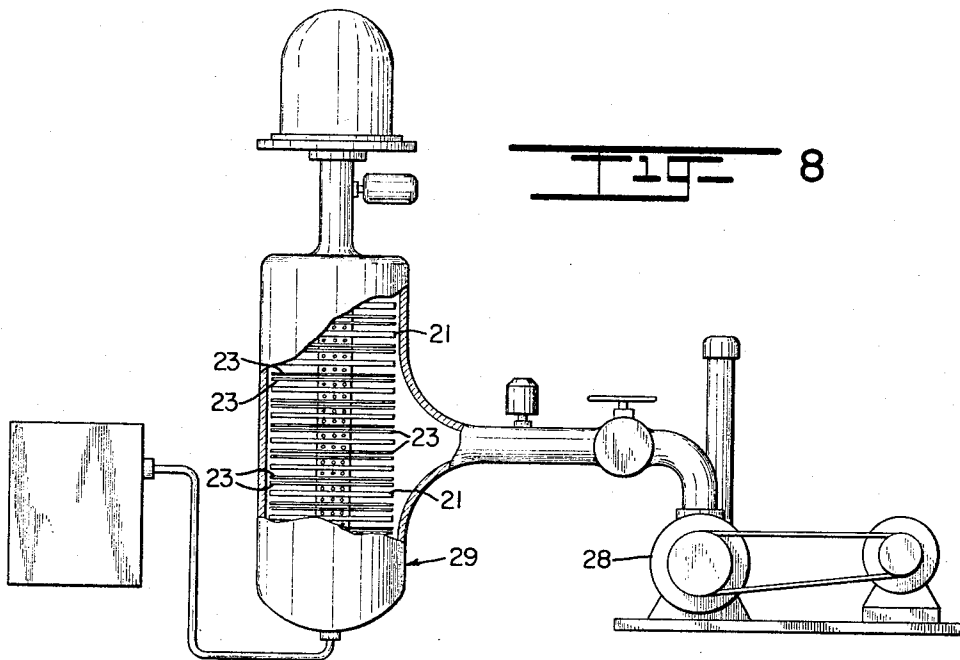
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TRAVELING WAVE HIGH FREQUENCY VACUUM PUMP

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4 Sheets-Sheet 4



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3,264,998 TRAVELING WAVE HIGH FREQUENCY VACUUM PUMP

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4 Claims. (Cl. 103—1)

This invention relates to a pump wherein the walls are flexible and are electrically or electrostatically perturbed to continuously produce waves which continuously travel along the pump at high frequency and propel the contents of the pump toward a point of expulsion.

Various types of pumps are used to produce high vacuums, but all of them suffer from various disadvantages. For example, diffusion vacuum pumps, such as those using oil diffusion, suffer from the problem of the back-streaming of vapor into the vacuum chamber being pumped. To avoid this difficulty, an elaborate system of baffled cold traps is used. Such traps reduce the pumping rate. Special plumbing, a special chamber and great care to seal and bake out the entire vacuum pump system are necessary.

The great need for obtaining clean evacuation in vacuum tubes led to extensive development of chemical and physical gas absorption techniques. Large, speedy absorption pumps using titanium as the absorption material have been developed. In the case of inert gases, however, the chemical absorption pumps are relatively slow. Furthermore, the chemical absorption material is easily poisoned. For example, in the case of titanium, an organic outgassing material in the vacuum chamber may react with and poison the titanium, or may not be absorbed and removed from the chamber.

Accordingly, it is an important object of this invention to provide a pump which will rapidly and efficiently produce a clean vacuum.

Another object of this invention is to provide a vacuum pump which will produce a high vacuum without the use of elaborate auxiliary equipment such as baffles, traps, refrigerating equipment, and special plumbing.

A further object of this invention is to provide a pump which will operate satisfactorily in the presence of inert gases or liquids as well as very reactive gases or liquids.

Additional objects of the invention will become apparent from the following description, which is given primarily for purposes of illustration, and not limitation.

Stated in general terms, the objects of the invention are attained by providing a pump which includes a series of resiliently mounted conductors, each insulated from each other, and mounted, preferably in parallel, in the same general plane. Juxtaposed to this plane of conductors, in parallel spaced relationship therewith, is a metal plate or sheet conductor. By sequentially applying a potential to each conductor of the series of conductors, and maintaining the metal plate neutral, the resilient plane of each conductor of the series will, in turn, deflect in and out in a wave motion at high frequency to provide a pumping action and move or propel gases or liquids from between the plane of the conductors and the metal plate toward a point of expulsion.

A dry pumping system was provided because it combines high pumping rate with minimum mechanical displacement of the pump's mechanism. The type of pump chosen has flexible walls which are perturbed so that displacement type waves move continuously along the pump structure. The individual displacement of each wave is small but the number of waves per second, or wave frequency, is quite large. This results in the production of a large order of effective volumetric displacement.

The velocity of the wave is of the order of about 5,000 to about 10,000 ft./sec. When pumping is carried out at low pressure, as is usually the case, pumped gas acquires a velocity approximately equal to that of the wave.

The traveling wave, in one embodiment of the invention, is produced by applying a polyphase electrostatic or magnetic field to the series of resilient coplanar conductors, which in effect constitute a tensed flexible diaphragm. This diaphragm usually is spaced about 0.02 to about 0.05 inch from the juxtaposed, parallel spaced, metal plate. The deflective action of the polyphase electrostatic or magnetic field of the pump sinusoidally propagates as many simultaneous waves as there are phases applied to the resilient conductors, while the wave velocity equals twice the wave frequency multiplied by the active length of the pump. For example, a pumping system having an active length of 24 inches, operating under 6 phases and a wave frequency of 2000 cycles per second, has an effective wave velocity of 8,000 ft./sec. and a wave delivery rate of 24,000 per second.

A more detailed description of specific embodiments of the invention is given below with reference to the accompanying drawings, wherein:

FIG. 1 is an isometric view showing the coplanar flexible conductors and the parallel spaced metal plate used in an electrostatically driven pump, with boundary insulation removed for clarity;

FIG. 2 is a cross-sectional view taken as along line 2—2 of FIG. 1 showing the rest position and the fully deflected position of the coplanar flexible conductors in an electrostatic pump employing the flexible conductors and metal plate shown in FIG. 2;

FIG. 3 is a schematic isometric view showing an electrostatically driven pumping system;

FIG. 4 is a schematic diagram showing a six phase vacuum tube oscillator for use in driving an electrostatically driven pump of the type shown in FIGS. 1, 2 and 3.

FIG. 5 is a schematic, partial plan view showing the manner of applying the high voltages to an electrostatically driven pump of the type shown in FIGS. 1, 2 and 3.

FIG. 6 is a partial end view showing a pump configuration constructed to generate a centrifugal pumping action;

FIG. 7 is a partial schematic diagram showing the direction of the wave motion in the pump of FIG. 6.

FIG. 8 is an elevational view, with portions broken away, showing a pump assembly employing stacked disc pump elements of the type shown in FIG. 6.

FIG. 9 is an isometric partial view showing an electromagnetically driven pump configuration; and

FIG. 10 is a similar view showing the force acting between adjacent conductors in the pump configuration of FIG. 9.

In the electrostatically driven pump of FIGS. 1, 2 and 3, the series of resiliently mounted coplanar conductors 10 is formed on a sheet of low vapor pressure plastic 11. The dimensions of conductors 10 are made preferably about 1 cm. by 25 cm., for example. The conductors 10 are positioned in parallel spaced relationship with respect to each other and are electrically insulated from each other by the plastic sheet 11, as best shown in FIG. 1. The strip conductors are made by metallization of strips of the plastic sheet 11 to form alternate metallized strips 10. Unmetallized insulating strips 12 are left between metallized strips 10. The plastic sheet 11 is made of a polyester plastic of about 2 microns thickness, such as the product of E. I. du Pont de Nemours & Company sold under the trademark "Mylar." Other suitable sheet plastic of suitable thickness can, however, be used. The conductor strips 10 are metallized aluminum produced by

vacuum vapor deposition techniques, but other suitable metals and other suitable techniques can be used.

The neutral or ground metal plate 13 is spaced about 0.05 inch in parallel spaced relationship with plastic sheet 11, and is made of sheet metal covered with a sheet of plastic, such as "Mylar," facing plastic sheet 11. As best shown in FIG. 2, boundary insulation 14, shaped to fit the curvature of the coplanar strip conductors 10 and plastic sheet 11 in the fully deflected position 11b, as contrasted from the rest position 11a (dotted lines), is sealed to the inner border portions of both plastic sheet 11 and the plastic cover of metal plate 13 to form a gas-tight seal therebetween. Counting from the left of FIG. 1, the first, fourth, seventh and tenth strip conductors 10 are electrically connected to line 15 of power source phase ϕA . Similarly, the second, fifth, eighth and eleventh strip conductors 10 are connected to power source phase ϕB through line 16, and the third, sixth, ninth and twelfth conductors 10 are connected to phase ϕC power source via line 17. The voltage of the three phase power sources is about 1000 to about 5000 volts, for example.

A typical vacuum pumping system in accordance with the invention is shown in FIG. 3, employing six power phases. The strip conductors 10, plastic sheet 11, unmetallized strips 12, metal plate 13 (not shown) and boundary insulation 14 are similar to those described in connection with FIGS. 1 and 2. Gas inlet and gas outlet zones are labeled, and the circuitry connecting the strip conductors to the power sources is shown. It includes two 6-phase output vacuum tube oscillators 16 and 17 connected to a metal common of 0.02", for example. Phase shifters 15a-15f also are connected to the common and in turn, are connected to amplifiers 20a-20f which, in turn, are connected to transformers 25a-25f, as shown. A film separation of 0.05", film thickness of 0.002", phase velocity of 2000"/sec., cubic displacement of 14,000 liters/sec., outlet pressure of about 10^{-3} Torr., frequency of 5000 c.p.s., R.M.S. voltage of 3500 v., power input of about 200 w., efficiency of about 20% and hysteresis loss of about 80%, are representative data for the system of FIG. 3.

A six-phase vacuum tube oscillator 16 or 17 of the type used with the circuitry of the pump shown in FIG. 3, is illustrated schematically in FIGS. 4 and 5. Transformers T_1 to T_6 are high voltage output audio type producing 2000 to 4000 volts. The inductance coils L_1 to L_6 of the transformers are used with capacitors C_1 to C_6 to generate 60° phase shift between vacuum tubes. This provides a total of 360° of shift around the ring oscillator to provide 6-phase output. The 6-phase oscillators 16 and 17 are self-excited. They are available on the market.

Cost-wise, the pump shown in FIG. 3 is comparable with a prior art diffusion type vacuum pump of equivalent capacity. Unlike the prior art diffusion and absorption type vacuum pumps, the pump of this invention can be opened to the atmosphere without damage to the pump while it is in operation. Because of the high molecular velocity of gases in the instant pump, a considerable amount of self cleaning action takes place, which minimizes back migration of pumped molecules and of outgassing occurrence from the pump and vacuum chamber walls. By using chemically inert plastic sheet, such as sheets made of fluorocarbon resins, for example, chemically reactive gases and vapors, such as fluorine, can be successfully pumped.

It will be understood that the geometry of the pump of this invention can be varied from that specifically illustrated hereinabove. For example, FIG. 6 illustrates a centrifugal pump configuration. In this centrifugal configuration the pumped gas is angularly accelerated and moves radially outwardly, as in a rotating structure. The flexible coplanar strip conductors 20 are spaced radially and insulated from each other by unmetallized plastic sheet strips 22 forming part of a plastic sheet disc 21. A

neutral or ground metal disc (23 in FIG. 7) is mounted coaxially with discs 21 and in axially spaced relationship therewith. A cylindrical container wall 24 is mounted concentrically around the discs. A gas inlet 25 is formed at the center of the pump structure and a gas discharge zone 26 is formed on the circumference of the structure as shown in FIG. 6. A six-phase power source is connected to the proper, respective strip conductors 20 in a manner similar to that described hereinabove with reference to FIGS. 1 and 3. The wave motion can be generated in a clockwise direction as shown by arrow 27 in FIGS. 6 and 7. FIG. 7 shows an edge view of discs 21 and 23.

Any number of pump elements can be stacked as shown in FIG. 8, to increase the pump capacity. Gas is spirally accelerated outwardly to near phase wave velocity and discharged into a vacuum roughing pump 28. If the pump 29 is a foot in diameter, the frequency is 5000 c.p.s., then the gas would be accelerated to near 3000 ft./sec. for about 5 disc units. The velocity of the gas is dependent upon the slippage between the gas and the phase wave and is about 50% of phase wave velocity.

An electromagnetically driven pump configuration of this invention is shown in FIGS. 9 and 10. Film conductors 31 and 32 are mounted on resilient membranes 33 and are wrapped around pump channels 34, as shown, with the aid of wall insulators 36, so that current in adjacent conductor sections will flow in the same direction. The film conductors are fixed to the membranes by any suitable manner. Current of one phase, ϕA is introduced into film conductor 31 and current of another phase, ϕB is supplied to conductor 32. As shown in FIG. 10, the current in adjacent sections of a conductor, such as conductor 31, induces a flux coupling resulting in magnetic attraction between adjacent conductor sections. This attractive force is used to move the surfaces of the membranes toward each other to produce gas pumping action in pump channels 34 in the manner described above for the force of electrostatic attraction. The inherent resiliency of the membranes causes them to return to normal position when the attractive force is removed.

For the operation of this type pump it is only necessary that each channel be constructed so that the direction of current flow of a particular phase is in the same direction in the top and bottom conductors. This will cause the top and bottom walls of the membranes to be pinched together with a force proportional to the instantaneous magnitude of the common current for any phase under consideration. All phases are wired in the same manner. One phase acts on the pump channel in the same manner as another phase. The only difference is the time sequence between phases. As in a polyphase motor, the phase order is important, i.e., the waves move either left or right handed depending on phase order. The magnetically driven version of the pump utilizes low voltage, 0.001 to 0.01 volt and relatively large current. This is achieved by suitable impedance matching transformers.

By using natural mechanical resonance of the pump channel membrane to match the power frequency both the electrostatic and the magnetic version can be made to act as a reactive load. This can maximize physical displacement and minimize driving power. A capacitive or inductive pick-up on the pump membrane can be used to feed a signal back to the driving oscillator to achieve this.

Obviously many other modifications and variations of the traveling wave high frequency vacuum pump of the present invention are possible in the light of the teachings given hereinabove. It is, therefore, to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically described and illustrated.

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What is claimed is:

1. A pump which comprises a series of conductors mounted on a planar resilient sheet which insulates said conductors from each other, a plate conductor disposed in parallel spaced relationship with the plane of said sheet means for maintaining the plate conductor electrically neutral, means for sequentially applying a potential to each of the resiliently mounted conductors to cause the same to deflect toward and from the plate conductor in a wave motion for moving fluid between the sheet and the plate conductor toward a point of expulsion.

2. A pump which comprises a first series of conductors mounted on a first planar resilient sheet which insulates said first series of conductors from each other, a second series of conductors mounted on a second planar resilient sheet which insulates said second series of conductors from each other, said second sheet being mounted in opposed relationship to said first sheet, a plate conductor disposed in spaced parallel relationship between said sheets, means for maintaining the plate conductor electrically neutral, means for sequentially applying a potential to each of the resiliently mounted conductors to cause the respective sheets to deflect toward and from the plate conductor in a wave motion for moving fluid between each of the sheets and the plate conductor toward a point of expulsion.

3. A pump which comprises a first series of radial conductors resiliently mounted on a flexible disc which insulates the conductors from each other, a second series of radial conductors resiliently mounted on a flexible disc which insulates the conductors from each other in a manner similar to the first series of conductors but in opposed relationship thereto, a disc conductor disposed in spaced parallel relationship between the planes of the

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two resiliently mounted conductors, means for maintaining the disc conductor electrically neutral, means for sequentially applying a potential to each of the resiliently mounted conductors to cause the same to deflect toward and from the disc conductor in a wave motion for moving fluid spirally between the planes of the two series of resiliently mounted conductors and the disc conductor from an inlet zone toward an expulsion zone.

4. A pump which comprises a first series of conductors mounted on a first resilient sheet which insulates said first series of conductors from each other, a second series of conductors mounted on a second resilient sheet which insulates the second series of conductors from each other, said second sheet being mounted in spaced relationship to said first sheet conductor means establishing electrical connection between opposite ends of a conductor in the first series of conductors with a parallel spaced conductor in the second series of conductors, means for sequentially applying current to each resulting pair of conductors to cause the same to deflect toward and from each other in a wave motion for moving fluid between said first and second sheets toward a point of expulsion.

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