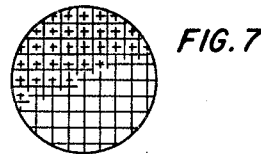
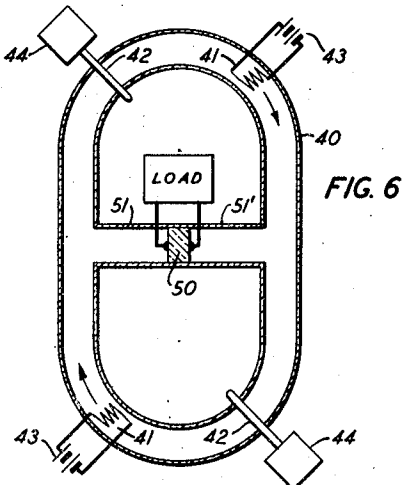
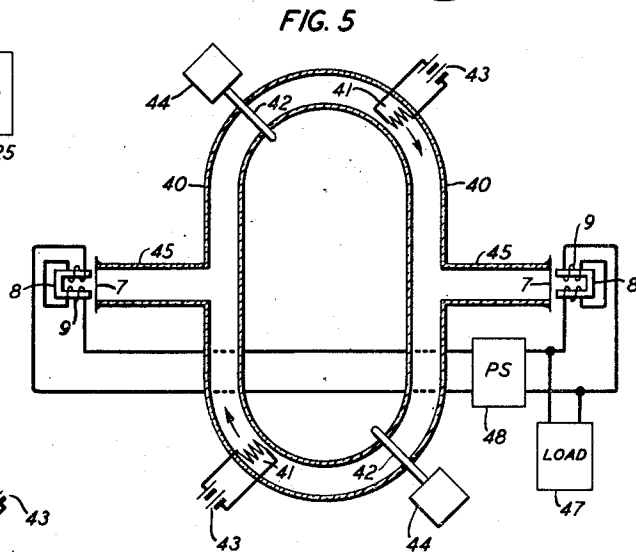
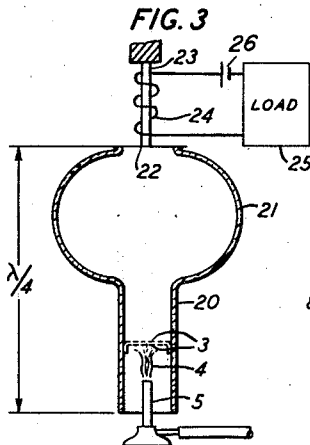
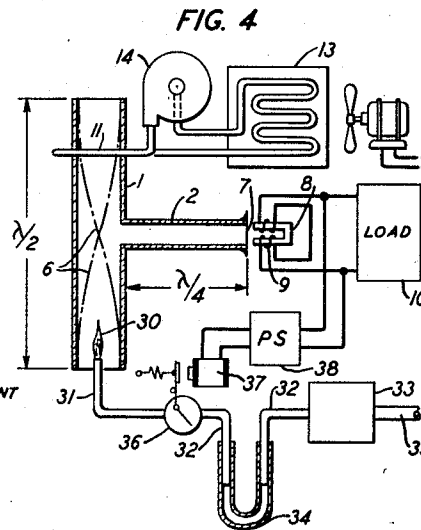
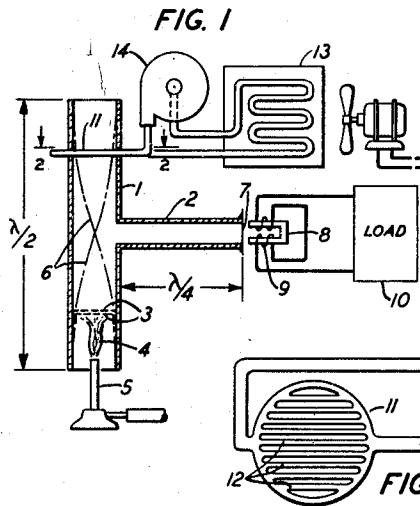


April 17, 1951

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ELECTRIC POWER SOURCE

2,549,464

Filed Oct. 29, 1947



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2,549,464

ELECTRIC POWER SOURCE

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Application October 29, 1947, Serial No. 782,703

1 Claim. (Cl. 290—1)

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This invention relates to electric power sources.

A general object of the invention is to derive electrical energy from heat energy in a novel manner. A subsidiary object is to derive electrical energy from the energy of vibration of a fluid column. A related object is to improve the efficiency of thermo-acoustic vibrating systems.

It is known that compression waves of considerable amplitude may be set up in a column of air, gas, vapor or other elastic fluid confined in a pipe or tube, by the application of heat at a suitable point. In a simple form of the apparatus a cylindrical tube or pipe, open at both ends, is provided internally with a heating element, such as a screen of wire gauze, disposed approximately one-quarter of the distance from the lower end of the tube to the upper end. Upon application of heat, as by a torch, to the screen, the fluid column, which in this case is a mixture of air and gases, breaks into violent oscillations, emitting a loud roaring sound. In a modified arrangement, the upper end of the tube is terminated in a resonant bulb or chamber. In still another modification, the heat may be applied directly, as by a flame, to the enclosed fluid column. If preferred, the heat of the flame may be applied externally to the walls of the tube. The oscillatory pressure pattern remains fixed with respect to the tube despite the steady convective flow of the fluid through the tube and away from the heat source. Thus the wave pattern advances with respect to the medium with a velocity equal to that of the medium with respect to the tube. These devices have in the past served as educational exhibits for illustrating acoustical phenomena and relations, such as the dependence of the frequency and wavelength of the sound emitted on the length of the vibrating fluid column.

It is a feature of the invention that such apparatus is put to use as a generator of electrical energy. To this end a suitable mechanical-electrical transducer, such as a telephone receiver, a magnetostrictive or a piezoelectric element is coupled, preferably by way of a suitable impedance matching transformer, to a suitable part of the vibrating fluid column. Compressional vibrations of the column are thus translated into electric currents which may then be supplied to a desired load. In addition, a part of the desired electrical energy may be fed back to control the timing of the application of heat, thus assisting in the maintenance of the oscillations.

In a modification, the tube is reentrant upon

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itself, thus providing a closed path for a circual fluid flow, and so conserving heat energy and increasing efficiency.

The invention will be fully apprehended from the following detailed description of preferred embodiments thereof, taken in conjunction with the appended drawings, in which:

Fig. 1 is a schematic diagram of apparatus in accordance with the invention in one of its simplest forms;

Fig. 2 is a cross-section of the apparatus of Fig. 1 taken at the section 2—2;

Fig. 3 is a schematic diagram of a modification of Fig. 1;

Fig. 4 is a schematic diagram of another modification of the apparatus of Fig. 1;

Figs. 5 and 6 are two alternative forms of a further modification of the apparatus of Fig. 1; and

Fig. 7 is a diagrammatic representation of a screen structure alternative to that of Fig. 1.

Referring now to Fig. 1, there is provided a tube or pipe 1, open at both ends and communicating with a second tube 2 at a point substantially midway between the two open ends of the first tube. Each tube may be of any suitable pressure resisting material, such as sheet metal or glass. The tube is preferably from 10 to 30 times its diameter. Thus, for example, it may be about 5 feet in length and 4 inches in diameter.

At a point intermediate the lower end of the tube 1 and its mid-point, for example, about one-fifth of the tube length from the lower end, there is provided a heating element which may comprise a screen of wire gauze, or a plurality of such screens 3 placed close to each other. This screen or screens may be shaped to fit the inside of the tube in any suitable manner and fixed in place in a plane approximately normal to the axis of the tube 1 either permanently or removably, as desired.

As is well known, upon the application of heat to the wire screen 3 by the flame 4 of a gas jet 5 or the like, the air or gas within the tube breaks into violent oscillations, standing compression waves are established and the tube emits a loud roaring sound. The wavelength of the fundamental component of the oscillations is approximately equal to twice the length of the tube. The mechanism by which this phenomenon takes place and whereby the steady heat energy applied to the screen 3 is converted into acoustical oscillatory energy has been many times described in the literature. In particular it is described in

"The Theory of Sound" by Lord Rayleigh, volume 2, pages 226-235.

While the oscillations are in progress, the oscillating velocity of the particles of air or gas is greatest at the two ends of the tube while the oscillating pressures are greatest at the mid-point of the tube. This condition is indicated by the broken lines 6 which show, approximately, the instantaneous velocities of the air particles at various points along the length of the tube at two successive half cycles of the oscillations, one half cycle apart.

In accordance with the invention, the pressure energy, which is greatest in the central region of the tube 1, is in part withdrawn to actuate a mechanical-electrical transducer. Thus a second tube 2 communicates with the vibrating air or gas column at the central point of the first tube 1. The second tube 2 is terminated in a vibratile diaphragm 7 which may be of conventional construction and which, when actuated by pressures within the tube, vibrates in the field of a permanent magnet 8, causing a current to flow in magnet winding 9 to which a load 10 may be connected.

Mechanical-electrical transducer elements of conventional form, including the telephone receiver schematically illustrated in Fig. 1, are characterized by impedances which, in the main, are high in comparison with the characteristic impedance of the vibrating air or gas column. Therefore, to withdraw substantial amounts of the energy of the vibrating column, some impedance matching device is desirable. A quarter wave impedance transformer is adequate for the purpose and accordingly the branch pipe 2 should be approximately one quarter wavelength from end to end, or, if preferred, an odd multiple of a quarter wavelength. The theory and operation of quarter wavelength transformers, both electrical and acoustical are well known per se and are described, for example, in "Electromechanical Transducers and Wave Filters" by W. P. Mason (Van Nostrand 1942). The quarter wavelength transformer or other impedance matching device is considered advantageous but is by no means essential, particularly because too perfect an impedance match between the vibrating air or gas column and the telephone receiver would result in too great a transfer of energy. If energy is withdrawn from the vibrating air column too rapidly the oscillations cannot be sustained.

It is to be understood that the pick-up device as shown in Fig. 1 may be replaced by any other suitable mechanical-electrical transducer, for example a piezoelectric element as in Fig. 6 or a magnetostrictive element as in Fig. 3.

The strength and the stability of the oscillations of the air or gas column are increased by the withdrawal of heat from a point intermediate the upper open end and the mid-point of this tube. To this end a cooling means 11 may be provided, for example, a screen of tubular members 12 as shown in Fig. 2, through the hollow meshes of which there flows a liquid such as water which may be circulated through a cooling radiator 13 external to the tube as by a pump 14.

Fig. 3 shows a modification of the invention in which the upper end of the tube 20 is closed by a bulb or resonator 21. Heat may be applied to a suitable point of the tube 20 by way of a heating element, such as wire gauze screens 3 as described in connection with Fig. 1. With this arrangement, high alternating pressures exist internally of the resonator 21 and the resonator wall therefore offers a suitable location for the

electromechanical transducer. Thus a vibratile diaphragm 22 may be mounted in an aperture in the resonator wall and a magnetostrictive member 23 provided with a winding 24 which may be connected to a load 25, may be mounted externally to the resonator so that when the diaphragm is actuated by pressures within the radiator, the member 23 is vibrated within the winding 24 and so modifies the current of a battery 26 flowing through the winding 24 to establish a varying current in a load 25.

Fig. 4 shows a further modification of the apparatus in which the wire gauze screens 3 and burners 4 of Figs. 1 and 3 are replaced by the flame 30 of a gas jet 31. This arrangement has the advantage that the heat may be applied intermittently and in synchronism with the oscillations of the air column in the tube 1, by alternately increasing and reducing the strength of the flame 30. Various means may be resorted to for this purpose and two are indicated in the figure. Thus the length of the gas pipe 32, measured from a reservoir 33 to the jet 31 may be altered as by adjustment of a U-tube 34 until this gas pipe is itself a resonant gas column having the same resonant frequency as the main tube. When this relation has been attained, and with suitable adjustment of the gas pressure in the gas main 35, then the alternate rise and fall of the pressure within the main tube 1 reacts on the jet 31 to cause alternate increase and reduction of the gas flow and therefore of the height and strength of the flame 30. Again, a valve 36 may be inserted in the gas pipe 32 which valve is alternately opened and partially closed in synchronism with the oscillations in the main tube 1. For example, the valve 36 may be operated by a relay 37 which is energized as shown. Electric current is supplied from the magnet winding 9, by way of an adjustable phase controlling device 38 to the relay 37. With this arrangement the strength of the oscillations in the main tube 1 and therefore the oscillatory energy which is available for withdrawal to the load circuit 10 is increased as compared with its value when the application of heat is steady.

With the open ended tubes of Figs. 1 and 4, some heat energy inevitably escapes to the atmosphere without contributing to the energy supplied to the load 10. To reduce these losses, the tube may be turned back on itself and made reentrant to provide a return path as indicated in Figs. 5 and 6. Thus in Fig. 5 there are two heating elements 41 and two cooling elements 42, so arranged around the endless tube 40 that the gas or air in its travel meets first an element of one type and then an element of the other. These elements are indicated schematically and each heater may be a wire screen or screens to which heat may be applied by external means, as by a battery 43. The cooling elements 42 may be of any desired type, for example, screens of tubular material as indicated in Figs. 1 and 2. They may be cooled by units 44 which may comprise pump, radiator and fan as in Fig. 1. The full length of the closed tube 40, measured along its axis around the circuit and back to the same point, is a full wavelength of the enclosed air or gas column or an integral number of full wavelengths. In operation, there is a small steady flow in one direction superposed on the rapid air or gas particle movement of oscillation. The direction of this movement depends on the arrangement and supply of the heating and cooling elements. Thus, if a large amount of heat is

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applied to the heater 41 at the lower portion of the left-hand branch of Fig. 5 and a smaller amount at the upper end of the right-hand branch, there will be a net convective flow of the air or gas in the tube in a clockwise direction and oscillations will be sustained. If the heating elements are placed at the lower part of the right-hand branch and at the upper part of the left-hand branch with the cooling elements between them, and the heat supplied to the former element exceeds that supplied to the latter, the convective flow will be in a counterclockwise direction and operation will be otherwise the same.

Energy of vibration may be withdrawn from suitable high pressure points of the system, for example from the mid-points of both tube branches. To this end a branch pipe 45 which may be one-quarter wavelength long communicates with one vertical leg of the closed tube 40 substantially at its mid-point, and a similar branch pipe 45' communicates with the other vertical leg at its mid-point. Each branch pipe 45, 45' may be terminated in a mechanical-electrical transducer which may be of the electromagnetic type described above and including a diaphragm 7, a magnet 8 and windings 9, or of any other suitable type. The outputs of these two transducers may be together fed to a desired load 47 and they may be connected in parallel, although it is preferred to interpose an adjustable phase adjusting device 48 between them to compensate for any phase displacement which may exist between the oscillating pressures of the two branch pipes.

Fig. 6 shows a variant of Fig. 5 in which a single mechanical-electrical transducer, here shown by way of example as a piezoelectric element 50, is coupled to both branch pipes 51, 51' of the reentrant tube 40. In other respects the apparatus of Fig. 6 may be the same as that of Fig. 5, and its operation is similar. As in the case of Fig. 5, the heat supplied to the upward flowing branch should exceed that supplied to the downward flowing branch by an amount sufficient to sustain the steady convective flow in one particular direction and overcome the retarding effect of friction against the tube walls.

The closed reentrant tube arrangements of Fig. 5 and 6 lend themselves to use with the vapor of a high boiling point liquid such as mercury. This serves to facilitate the interchange of heat energy from the vibrating fluid column to the heater screens 41 and increases the efficiency of energy transfer to a high impedance mechanical-electrical transducer such as the piezoelectric element 50.

Wherever a wire gauze screen is employed, improved results may be obtained by the use of several such screens placed close together with their openings staggered so that as much as

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possible of the fluid passing through the screen comes into immediate contact with one or other wire of the mesh, thus facilitating transfer of heat from the wire screen to the fluid. This construction is shown in Fig. 7.

What is claimed is:

A source of oscillatory energy comprising a tubular resonator, an elastic fluid within said resonator and capable of supporting standing compression waves of wavelength and frequency determined by the dimensions of said resonator, means for periodically applying heat at a selected point of said resonator to said fluid, whereby standing compression waves are developed in said fluid, means, including a mechanical-electrical transducer coupled to said fluid, for withdrawing a portion of the oscillatory energy of said compression waves, and means for feeding back a portion of the output of said transducer to control the timing of said periodic application of heat.

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