May 27, 1958 W. A. MARRISON 2,836,033

HEAT-CONTROLLED ACOUSTIC WAVE SYSTEM

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FIG. 1

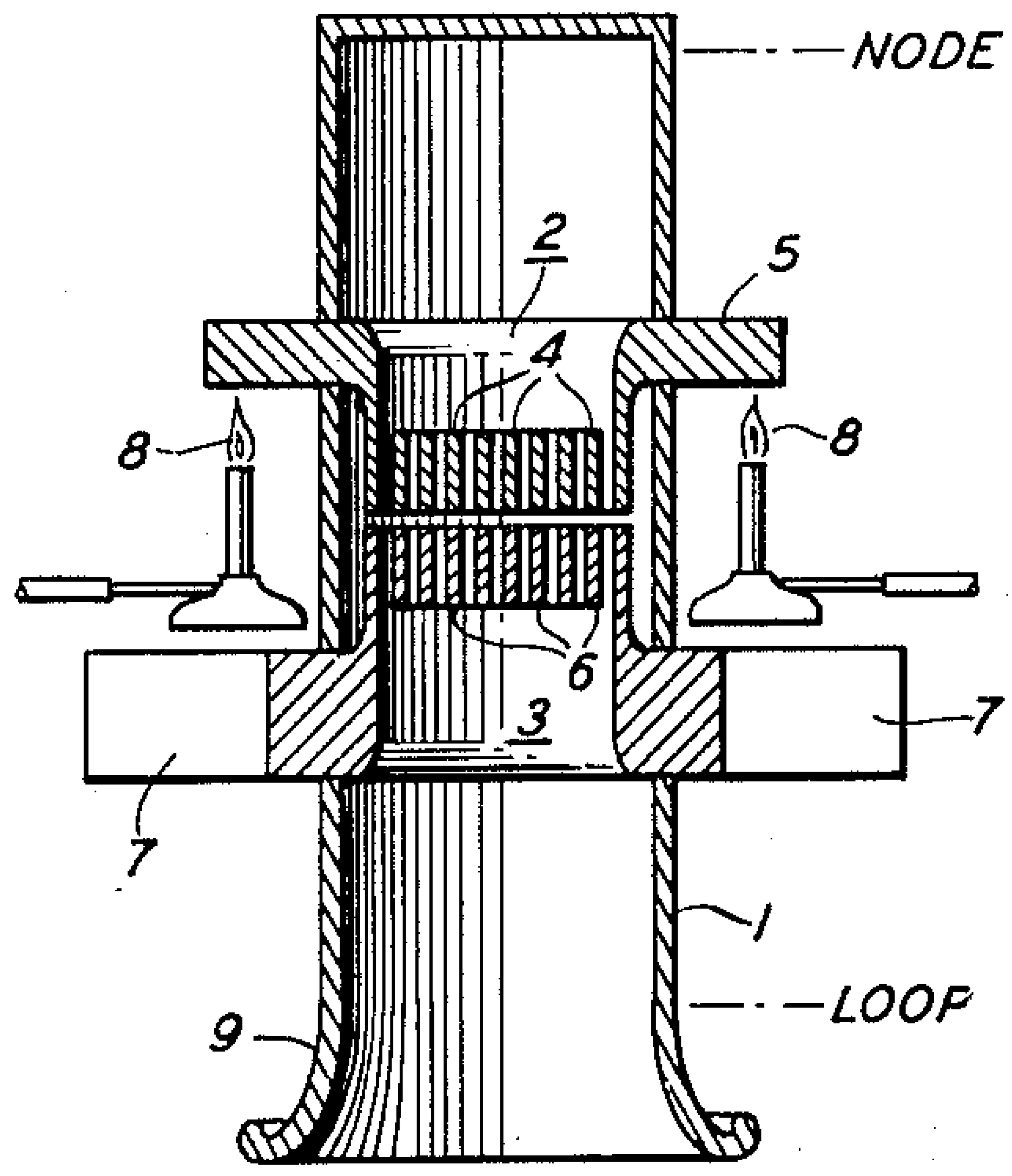


FIG. 2

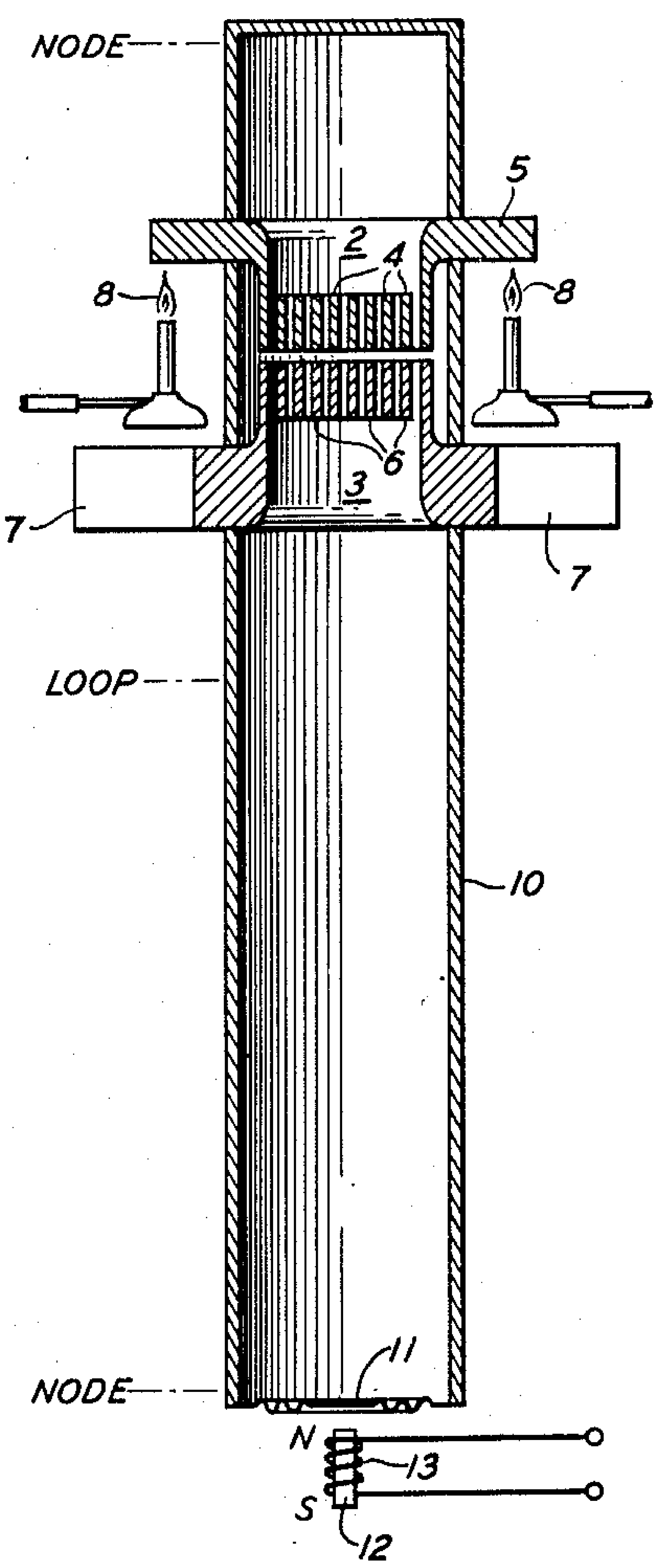
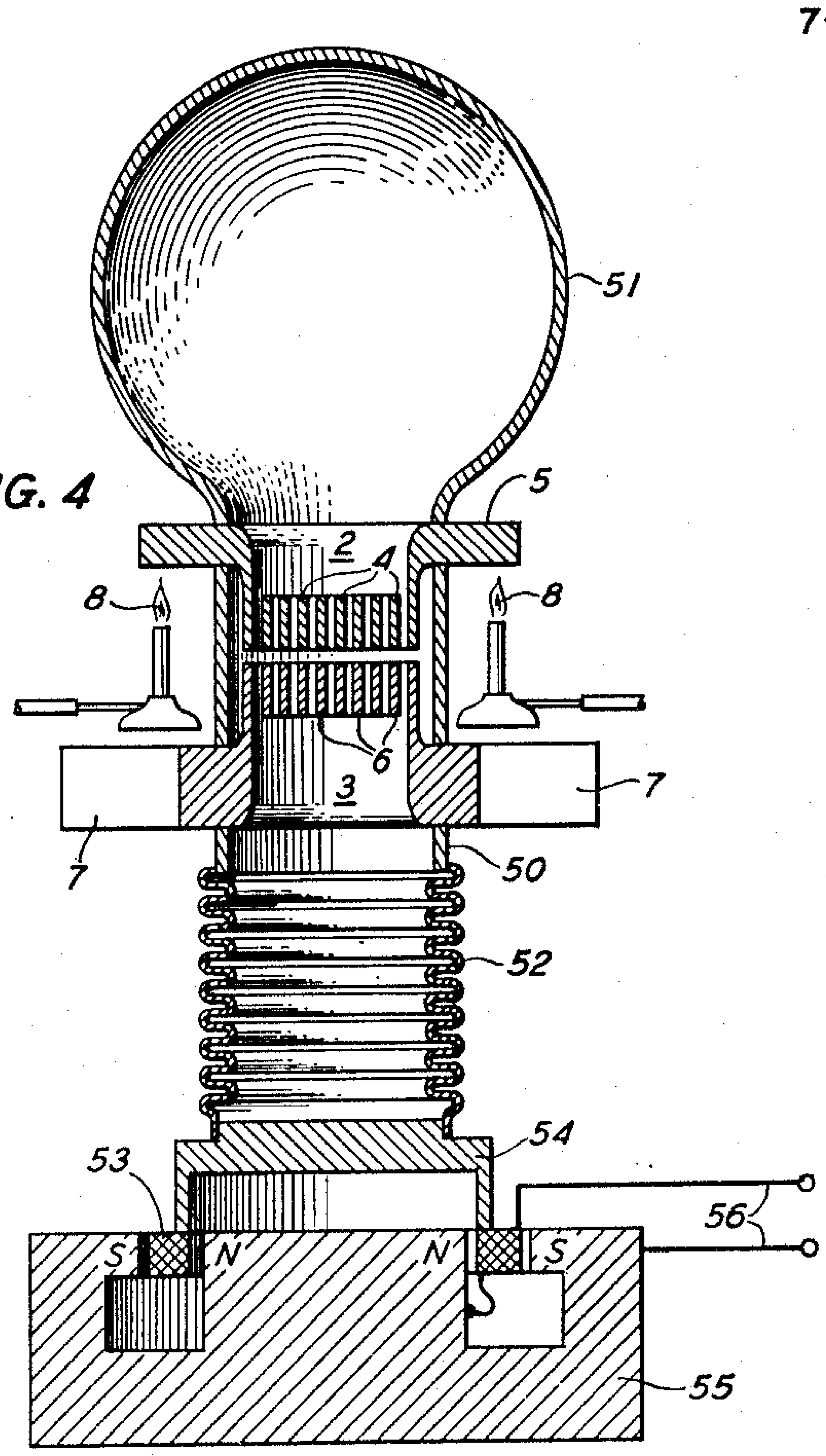


FIG. 4



INVENTOR
W. A. MARRISON
BY Harry C. Hart
ATTORNEY

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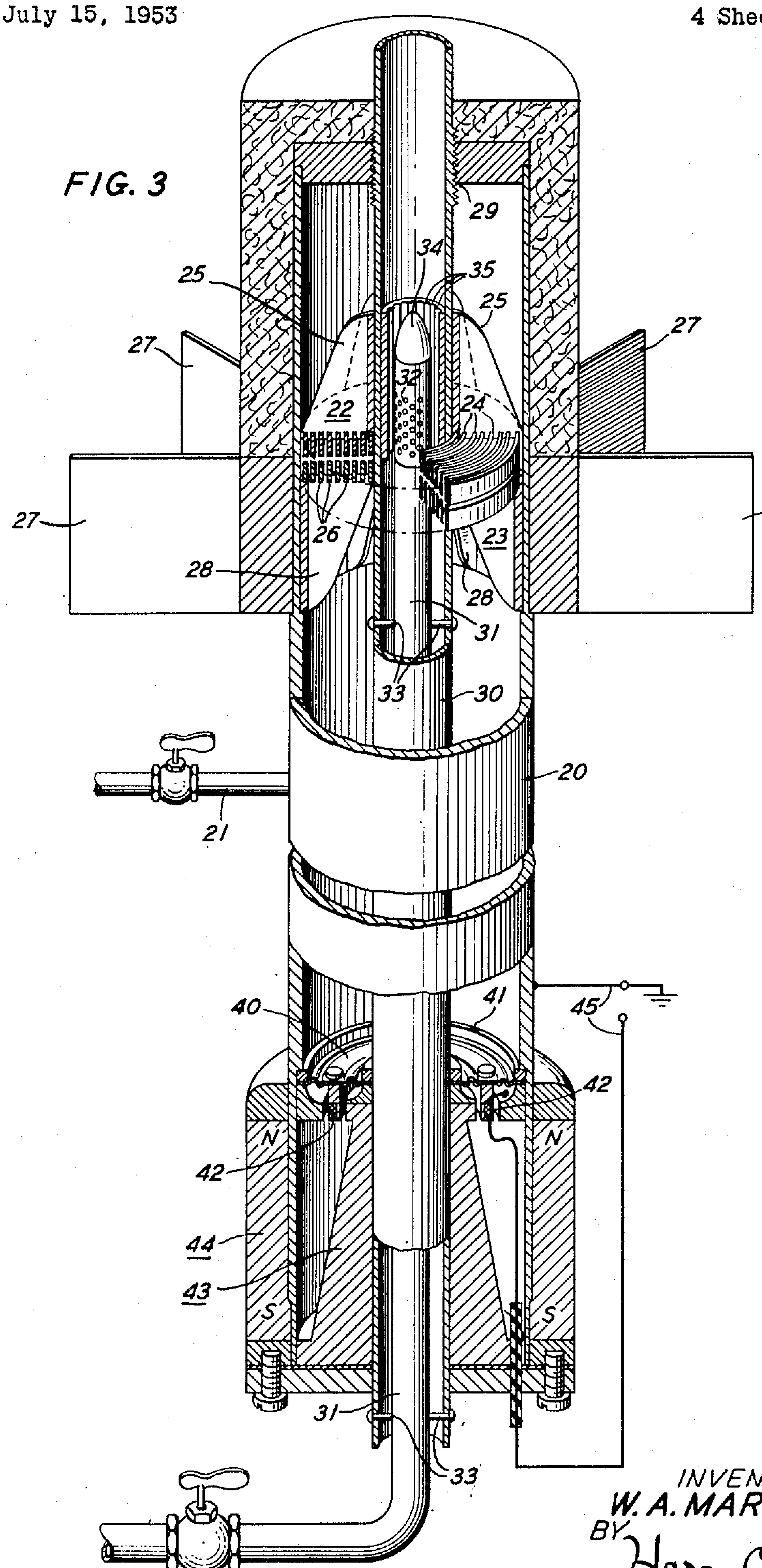
FIG. 3



INVENTOR
W. A. MARRISON
BY Harry C. Hart
ATTORNEY

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FIG. 5

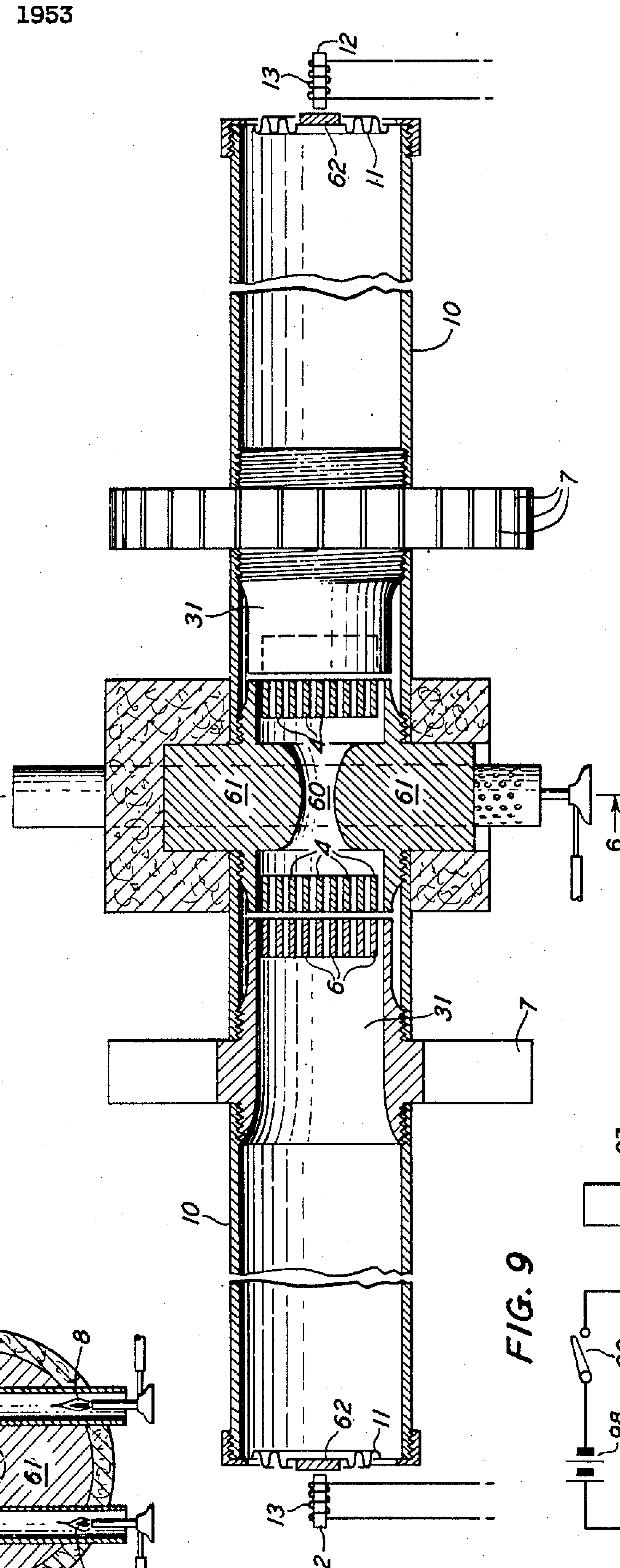


FIG. 6

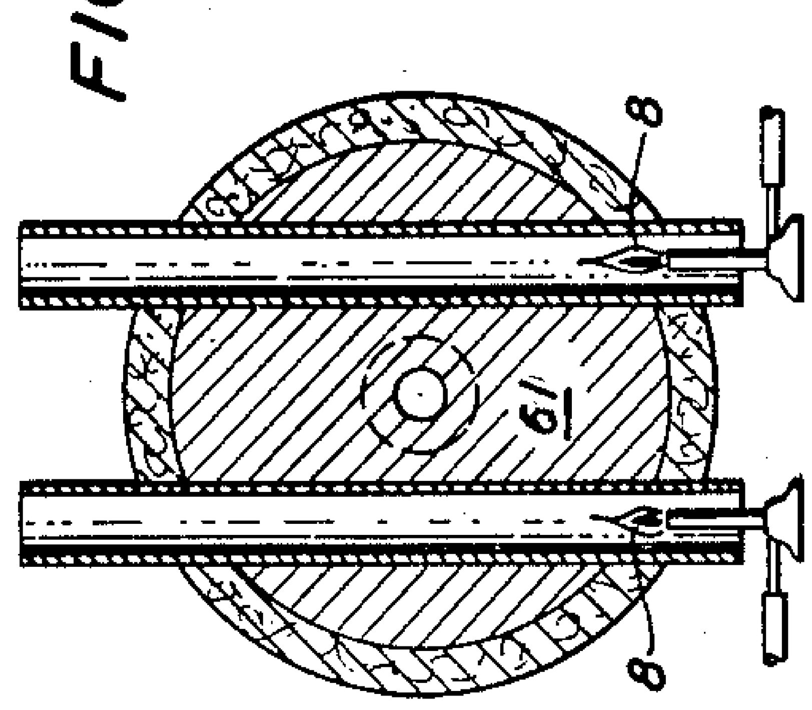
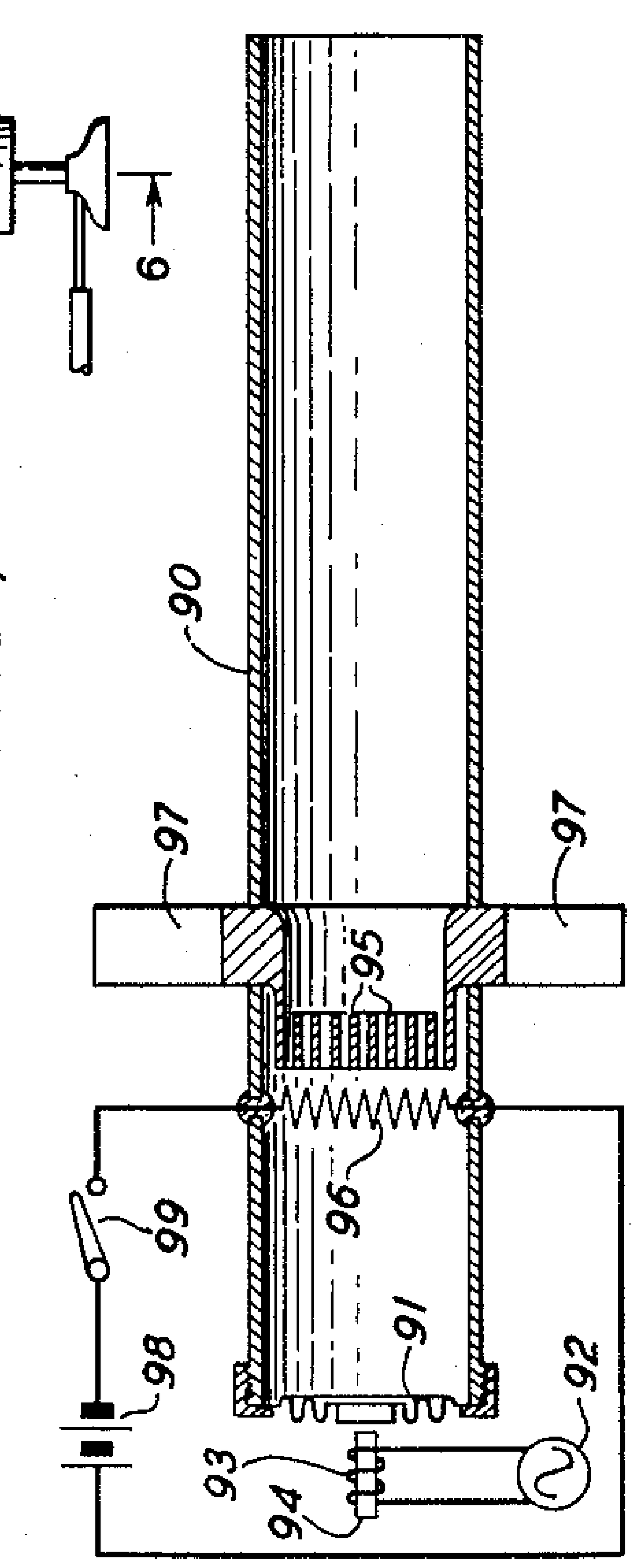


FIG. 9



INVENTOR
W. A. MARRISON
BY Harry C. Hart
ATTORNEY

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FIG. 7

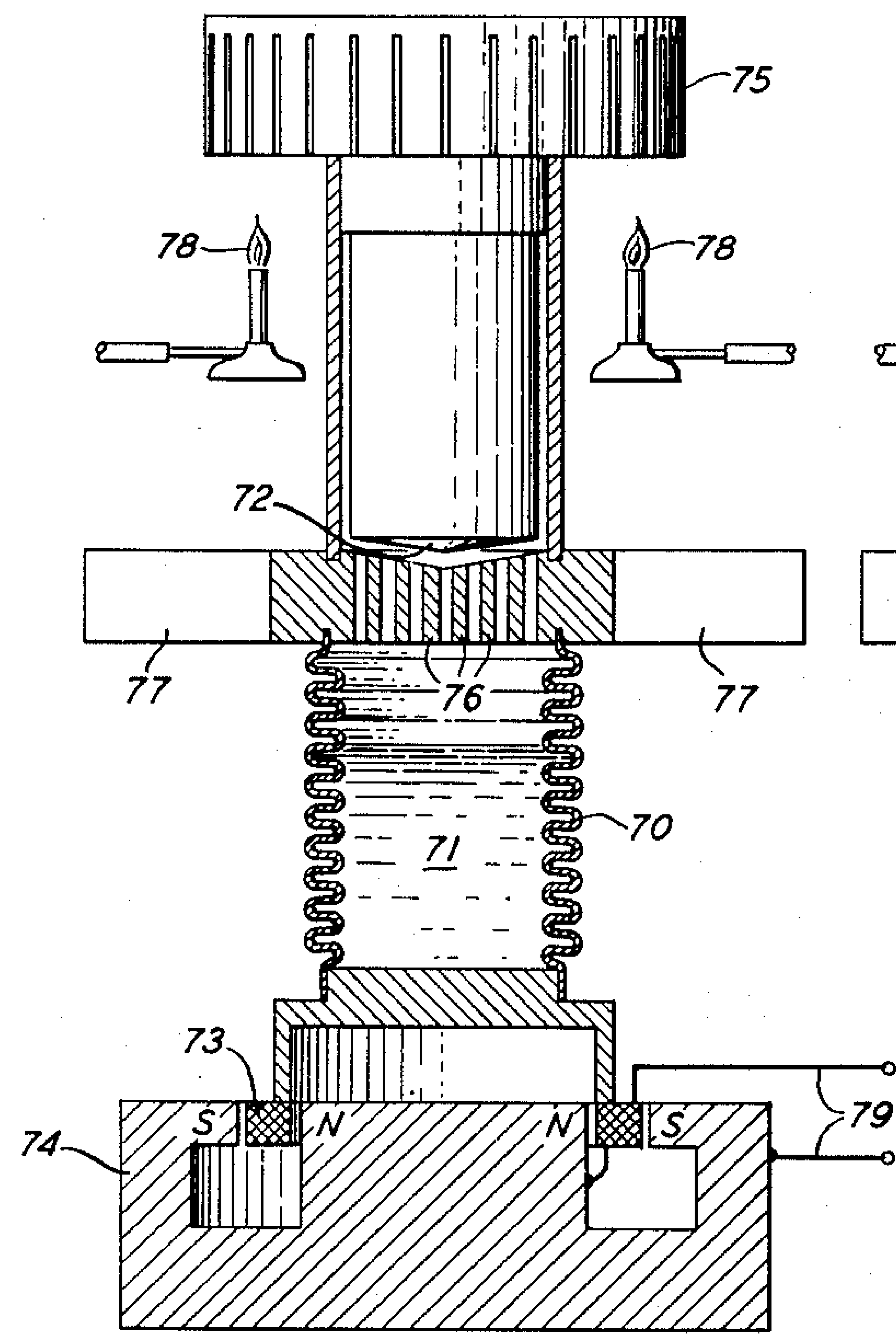
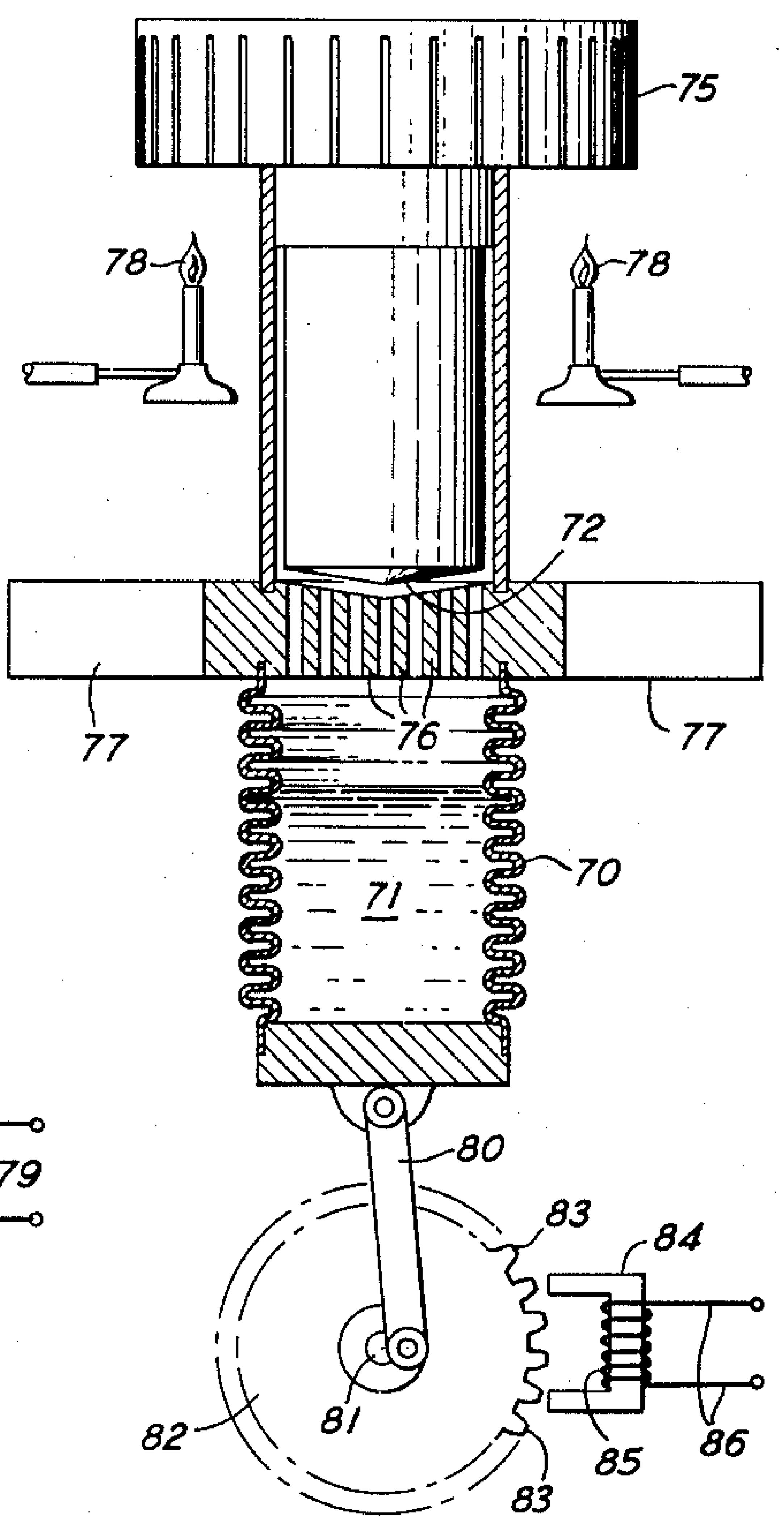


FIG. 8



INVENTOR
W. A. MARRISON
BY Harry C. Hart
ATTORNEY

United States Patent Office

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2,836,033

HEAT-CONTROLLED ACOUSTIC WAVE SYSTEM

Warren A. Marrison, Berkeley Heights, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application July 15, 1953, Serial No. 368,185

23 Claims. (Cl. 60—24)

This invention relates to heat-controlled acoustic wave systems.

The principal object of the invention is to sustain acoustic oscillations in an elastic fluid as a working medium by the application of heat to it and the abstraction of heat from it in an effective manner. A related object is to amplify acoustic wave energy by such application and withdrawal of heat. A particular object is to convert the energy of burning fuel into energy of acoustic vibration without resort to rotating parts and with a minimum of movement of mechanical masses. Such acoustic vibratory energy is useful in many connections, for example in the supply of operating power to telephone apparatus at an unattended repeater station.

It is known that by the application of heat to one part of a confined column of an appropriate fluid, such as gas, a liquid or a vapor, and the extraction of heat from another part, the fluid column may be set into longitudinal vibration. It has already been proposed to convert the vibration energy into electrical energy by way of a transducer and to utilize this electrical energy in any desired fashion, for example to supply the bias voltages and currents required for the operation of an amplifier or other component of an unattended telephone repeater station. So far as is known, however, such apparatus is open to the objection that its efficiency is low.

The present invention is based in part upon the discovery that by the location of the element by way of which heat is supplied to the vibrating fluid column in optimum relation to the location of the element by way of which heat is withdrawn from it, a great improvement in efficiency may be obtained. In accordance with the invention in one of its principal forms, there is provided a container, for example a cylinder of length several times greater than its diameter, closed at one or both ends, and filled with a wave-supporting fluid medium, preferably a gas. When the column of fluid defined by a cylinder having one open end is set into longitudinal vibration, a vibration node exists at a closed end and a vibration loop exists at an open end. To the contrary, in the case of a cylinder in which both ends are closed, a node exists at each closed end and a loop exists at a distance removed from the node by a quarter wavelength. A heater member and a cooler member are located approximately midway between such a vibration node and such vibration loop. In particular, in the case of the column which is closed at both ends, these members are located approximately half way between one closed end of the column and its center. Each of these members has the form of a screen of strips which extend axially for a distance substantially equal to the amplitude of vibration of the fluid. They are equally spaced close together, indeed as close as possible without defeating the purpose of the invention by physical contact. The transfer of heat from one to the other by conduction and radiation is minimized by appropriate surface treatment. With this construction, each fluid molecule which passes through the heater-cooler pair is heated during substantially one half of its vibration cycle and cooled throughout substantially the other half. In accordance with a further feature of the invention, the heater member is located between the cooler member and the vibration node. With this arrangement the expansions and contractions of the gas which take place due to this alternating heating and cooling action are in such phase as to promote oscillation.

For operation in this fashion it is required that the phase of the transfer of heat from the heater member to the fluid moving into the heater member be somewhat lagging with respect to the physical displacement of this part of the medium to which this heat energy is imparted. With proper construction, this phase lag is obtained by virtue of the length of time required for the transfer of heat from the heater member to the working medium. In other words, as any fluid element passes into the heater member, the transfer of heat from the heater member to it commences immediately, but is not completed until after the fluid has completed its excursion and is on the way back to the cooler member.

Construction of the apparatus in accordance with the present invention optimizes this phase lag by providing for proper correlation of the dimensions of the heater member with the constants of the working medium and the oscillation period. Specifically, when the working medium is a gas, and provided the foregoing restrictions are also met, a satisfactory phase relation can be established when these constants are related in accordance with the following formula:

$$T=\frac{cdl^2}{2k}$$

where

T=the oscillation period
c=the mean specific heat of the gas
d=the density of the gas
l=the spacing between the strips
k=the thermal conductivity of the gas

all expressed in consistent units.

By the same token, the abstraction of heat from the working medium by the cooler member should lag the oscillatory displacement into the cooler member, provided the latter is located as described above with respect to the oscillation node and the heater member. Provided again that the working medium is a gas, the cooler member is preferably designed in accordance with the same formula.

In an elastic fluid which is undergoing longitudnal vibration, the velocity node is a point of maximum oscillatory pressure. More generally, therefore, the heater-cooler pair of the invention are disposed in the manner described above with respect to a point of maximum oscillatory pressure. In the case of an elastic fluid body which is driven into vibration by external means as distinguished from undergoing self-oscillatory vibrations, such a point of maximum pressure appears at the face of the driving member which may be a piston, the face of a piezoelectric crystal, an electromagnetically actuated diaphragm, or the like. In such a system the heater-cooler pair, when disposed in the fashion described above with respect to this point of maximum oscillatory pressure, may be regarded as furnishing negative resistance into which the driver works, and the apparatus which embodies them thus operates to amplify the acoustic energy applied by the driver to the medium.

Oscillations of large amplitude can in this way be produced. With an open-ended tube, a loud noise, which may serve as a fog horn or an alarm, is generated. More usually, however, an electrical output is desired, the noise being undesirable. For such purposes, a tube closed at both ends and constructed of rigid material such as brass or steel is recommended. By the provision of a transducer of conventional design at an appropriate point of the apparatus, the energy of vibration of the fluid column may be converted into electrical energy for use as desired.

If desired, a pair of like units may be mounted in end-to-end relation and acoustic coupling may be provided to maintain their vibrations in dynamic balance.

The invention is in part also applicable to a heat engine of the 2-phase type, e. g., a liquid phase and a vapor phase. In such apparatus the vapor phase is caused to expand and contract due to alternate vaporization of a small fraction of the liquid and recondensation thereof. These expansions and contractions operate to move a portion of the liquid in bulk and this movement may be converted into reciprocating or rotary movements by known mechanisms. By the location of a cooling element in the optimum position relatively to the point at which heat is applied to the vapor, improved performance of such apparatus ensues.

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

Fig. 1 is a diagrammatic cross-sectional view of a noise generator in accordance with the invention;

Fig. 2 is a diagrammatic cross-sectional view of a power generator in accordance with the invention, reduced to simplest form;

Fig. 3 is a diagrammatic cross-sectional view of preferred apparatus in accordance with the invention;

Fig. 4 is a diagrammatic cross-sectional view of a variant of the generator of Fig. 3;

Fig. 5 is a diagrammatic cross-sectional view of a pair of generators in accordance with the invention coupled together in end-to-end fashion for balanced operation;

Fig. 6 is a sectional view of the apparatus of Fig. 5 taken at the section **6—6**;

Fig. 7 is a diagrammatic cross-sectional view of a modification of the invention;

Fig. 8 is a diagrammatic view of a variant of the apparatus of Fig. 7; and

Fig. 9 shows an acoustic amplifier embodying the principles of the invention.

Referring now to the drawings, Fig. 1 shows a cylindrical tube **1** of rigid material such as steel or brass pipe. Its upper end is closed and its lower end is open. Approximately midway between its upper end and its lower end there are provided a heater member **2** and a cooler member **3**, the heater being located above the cooler, that is, between the cooler and the closed end of the tube. Each of these members may comprise a grid or screen of strips of sheet metal disposed parallel with each other and equally spaced apart, and aligned with those of the other member and axially of the tube in such a fashion as to provide the freest possible passage of a fluid entirely through both members. The strips **4** of the heater member **2** are conductively fixed as by welding to a flange **5** which extends outward through the walls of the cylinder. The strips **6** of the cooler member are similarly fixed in heat-conductive fashion to cooling fins **7** which likewise extend outwardly through the cylinder walls. Heat is applied to the flange **5** as by way of gas burner flames **8**. The heat travels to the metal strips **4** of the heater member **2** by metallic conduction and is transferred to the gas within the tube by reason of gaseous conduction and its motion past the surfaces of these strips in the course of its vibrations. In reverse fashion, heat is withdrawn from the gas which passes between the metal strips **6** of the cooler member **3** and is withdrawn by metallic conduction to the cooling vanes **7** where it is conveyed to the exterior of the apparatus by conduction and convection to the atmosphere.

Application of heat to a device of the proportions

shown results in the establishment of longitudinal vibrations within the tube **1** which are of substantial amplitude. The wavelength of such vibrations is four times that of the tube **1** itself, a node appearing at the closed upper end and a loop at the open lower end. In other words the tube is one quarter wavelength long. It might equally well have a length of three, five, or any odd number of quarter wavelengths, with appropriate terminations at the ends of the tubes. To match the impedance of the device to that of the air and so transfer a maximum amount of power, the open end of the tube **1** may be provided with a bell or horn **9**. This apparatus generates a loud noise which may serve as an alarm, a fog horn, or the like.

If preferred, the known principles of organ pipe design may be followed in the construction of a pipe which is highly resonant to a particular preassigned frequency and resonant to harmonics of this frequency to a desired extent. As so constructed the acoustic oscillator of Fig. 1 gives a musical tone of preassigned pitch and quality, and the apparatus may be employed as an organ pipe. In this event, it may be desirable to provide for the rapid starting and stopping of the oscillations, to which end an electrical heater element in the form of a grid of resistance wires may be preferred. Application of electric energy from a battery or other suitable source by manual control of a switch acts to set the pipe into oscillation and to terminate such oscillations as desired. Such a system is shown in Fig. 9, which is described more fully below.

Fig. 2 shows a tube **10** which may be of the same general construction as the tube of Fig. 1, but of approximately twice its length and closed at both ends. It is filled with a suitable fluid, preferably an inert gas such as argon, neon, or helium, or a mixture of such gases. In accordance with the known principles which govern standing acoustic waves in closed cylinders, such apparatus sustains longitudinal fluid vibrations in which a node exists at each end and a loop midway between the two ends. To maintain these vibrations, a heater member **2** and a cooler member **3** which may be of the same construction as those of Fig. 1 are located from one third to one half of the way from the node to the loop, the heater being again above the cooler. In this case, the length of the tube is one half the vibration wavelength. It might equally be any multiple of a half wavelength. Because the fully closed apparatus of Fig. 2 conserves energy more than the open-ended tube of Fig. 1, longitudinal vibrations of even greater amplitude may be established. To convert their energy into electrical energy, it is only necessary to provide a transducer of any desired variety and locate it at a point of the vibrating gas column which is appropriate from the standpoint of impedance matching. The vibration node is a high impedance point and for most purposes it is preferable to draw the output from such a point. Accordingly, a transducer of the simplest variety, namely, of a diaphragm **11** of magnetizable material, hermetically sealed to the walls of the tube **10** and providing one end closure for the tube, is associated with a magnetized ferromagnetic core **12** on which is wound a coil of wire **13**. As the diaphragm **11** moves under the influence of the fluid vibrations, electrical energy is generated in the coil which may be applied to any desired load.

Fig. 3 shows the constructional details of apparatus which embodies the foregoing principles as well as certain refinements thereof. As before, a cylindrical tube **20** of rigid material such as brass or steel is provided. Within this tube is a second tube **30** of smaller diameter. The outer tube **20** is closed at each end by a ring whose inner diameter fits snugly around the wall of the inner tube, thus leaving the inner tube **30** open at both ends. Within the inner tube is a third tube **31** which serves merely to carry fuel such as illuminating gas or a combustible vapor mixture, or a mixture thereof with air, to a burner **32**. The tube **31** may be held in coaxial alignment with the tube **30** by pins **33**. The burner **32** may conveniently comprise a plurality of small holes which pierce the wall of the tube **31** through which the fuel passes. Additional air for combustion may pass upward inside of the tube **30** and outside of the tube **31**. With this construction a very hot flame surrounds the burner **32**, and the body of the burner itself glows red hot. Loss of its heat in the upward direction may be minimized by a white ceramic cap **34**, mounted on top of the burner.

To receive and absorb the heat of the flame to maximum extent, the inner wall of the tube **30** may be provided, especially in the neighborhood of the burner **32**, with a number of indentations or corrugations **35** which act greatly to increase its heat-absorptive surface as compared with that of a smooth-walled tube of the same mean diameter. This corrugated surface is fixed, by way of the tube walls, to upper extensions **25** of the heater member **22** in heat conductive fashion as by welding, soldering, or otherwise. Each of these upper extensions is similarly conductively fixed to a number of concentric rings **24** of sheet metal which serve as the vanes by way of which the heat of the flame of the burner **32** is ultimately delivered to the vibrating fluid.

Similar rings **26** are located close to, and in alignment with, the heater rings **24** and immediately below them. These cooler rings are similarly fixed to flanges **28** and these flanges in turn are fixed to the walls of the outer tube **20** and to cooling vanes **27** which extend radially outward therefrom.

Precise adjustment of the distance separating the heater rings **24** from the cooler rings **26** may be secured by coupling the inner tube to the outer tube at some point, e. g., the upper ring closure, by way of a screw thread **29**. Rotation of the inner tube **30** with respect to the outer one **20** then acts to increase or diminish the axial spacing of one set of rings **24** from the other **26** and thus to adjust their separation to the optimum value. Heat transfer by radiation from one set of rings to the other may be minimized by polishing the ring surfaces, especially those which face each other.

For optimum results, the full distance from the node end of the heater to the loop end of the cooler should be substantially equal to the full peak-to-peak excursion of the vibrating gas molecules in the vicinity of the heater-cooler pair. With a tube of about 30 centimeters total length, closed at each end, molecular peak-to-peak excursions as great as one centimeter are obtainable. When the heater-cooler pair are located as recommended, approximately midway between the node and the loop, the peak-to-peak excursion at this point of the standing wave is reduced to about 7 millimeters. Therefore, allowing for a spacing between the heater and the cooler of not more than one millimeter, the axial depths of the heater strips and of the cooler strips should both be about 3 millimeters.

The lower end of the annular vibrating column is terminated by an annular diaphragm **40** whose outer periphery is fixed to the outer tube **20** while its inner one is coupled snugly to the inner tube in rotatable fashion. A small passage **41** may be provided in the outer retaining ring, leading from the upper face of the diaphragm to the lower one. It serves to equalize pressures on the two sides and so to prevent static deflection. A coil **42** is fixed to the diaphragm **40** in position to move freely in the annular air gap of the yoke **43** of a magnet **44**. With this construction, vibration of the annular gas column contained between the tube **20** and the tube **30** actuates the diaphragm **40** and an electrical voltage appears at the terminals **45** of the coil, and this may be supplied to any desired load.

A pipe fitting **21** serves to admit the vibrating medium into the annular space between the outer tube **20** and the inner tube **30**, or to withdraw it. This medium is preferably an inert gas such as helium, argon, or neon, or a mixture of such gases. Variation of the proportions of such components of different molecular weights varies the frequency of vibration. Inertness is desirable to prevent corrosion of metal surfaces. For the same reason it is desirable to exclude all oxygen and water vapor from the annular chamber.

The working medium may, if desired, be operated at pressures substantially in excess of atmospheric pressure. Higher pressure results in higher vibratory energy per unit of volume, and therefore in a higher power output for apparatus of the same overall size.

The arrangement of heater and cooler elements described above in connection with Figs. 1, 2 and 3 may also be applied to an energy source in which the elasticity function is largely concentrated at one end while the inertial or mass function is largely concentrated at the other end. Fig. 4 shows such a construction in which a tube **50** is provided at its upper end with an enlargement or bulb **51** and at its lower end with an expansible bellows **52**. Between the bulb **51** and the bellows **52** a heater-cooler pair may be mounted having identically the construction of these elements in Figs. 1 and 2, like parts being similarly numbered. A coil **53** may be mounted by way of a bracket **54** on the lower end of the bellows **52** in position to travel vertically in the air gap of a magnet **55**.

When heat is applied as by way of a flame to the heater element **2**, the gas within the entire structure is set into vibration and the resulting oscillatory pressures cause the movable coil **53** to be reciprocated in the air gap of the magnet **55**. This movement results in the generation of an electric voltage which appears at the terminals **56**. It may be utilized as desired.

Fig. 5 shows a pair of devices of the type shown in Fig. 2 juxtaposed in end-to-end relation for dynamic balance. In order that there shall be adequate coupling between the two vibrating gas columns, a channel **60** is provided which interconnects them. The ends of the two columns which are spaced most nearly together would be vibration nodes were it not for the provision of this channel. The effective nodal plane for both columns is thus in the approximate center of the interconnecting channel **60**. For this reason the heater-cooler pair is in each case spaced relatively close to the central plane. Heat may conveniently be applied to a heater **61**, which is common to both tubes **10**, by way of burners **8** as indicated in the cross-sectional view of Fig. 6.

In the operation of this balanced arrangement, the movement of the gas at any instant is either inward toward the central plane of both cylinders **10** or outward toward the separated ends of the two cylinders. Thus, the vibration of each gas column finds a reaction in the vibration of the other gas column so that dynamic balance is secured and external vibration, shaking of the mount, noise, and the like, are minimized.

The energy of each vibrating column may be withdrawn by way of a transducer mounted near a vibration node. Two such transducers are shown, one at each of the separated ends. Each may comprise a diaphragm **11**, having mounted on it a magnetizable slug **62**, juxtaposed with a core **12** on which is wound a coil **13**.

Their electrical outputs, derived in the fashion heretofore described in connection with Fig. 2, may be connected in parallel or in series, as desired, and supplied to any desired load.

Fig. 7 shows another form of resonant heat engine in which a closed chamber is itself constructed principally of an expansible bellows **70**. The chamber is largely filled with a vaporizable liquid **71**; e. g., an ether, a saturated hydrocarbon, or, aside from the problem of corrosion, water. The upper surface **72** of the chamber is heated as by the application of heat from a gas flame **78** to the outwardly extending flange **75** which is integral therewith. This upper surface **72** is preferably pitted or corrugated to increase the area of its surface as compared with that of a flat surface of the same overall extent. A grid or screen of sheet metal strips **76** is provided between the upper surface of the liquid **71** and the upper bound **72** of this chamber, and these strips are conductively fixed in suitable fashion to cooling fins **77** which extend outwardly of the apparatus. In operation, a portion of the liquid is alternately vaporized by coming in contact with the hot upper bound **72** of the chamber and condensed by coming in contact with the cooling strips **76**. This results in alternate expansion and contraction of the vapor which lies above the liquid surface and so alternately drives the liquid **71** downward, extending the bellows **70**, and upward, compressing the bellows. A coil **73** may be fixed to the lower end of the bellows **70** and may be arranged to move in the air gap of a permanent magnet **74**, thus to generate electrical energy which may be withdrawn from the coil terminals **79**.

Fig. 8 shows a modification of Fig. 7 which may be of the same construction and, insofar as the heat engine portion thereof is concerned, operates in the same fashion. Instead, however, of operating to reciprocate a winding in the air gap of a magnet, extension and retraction of the bellows **70** operates to advance and withdraw a connecting rod **80** and so to rotate a shaft **81** which bears a toothed wheel **82**. Movement of the teeth **83** past the poles of a magnet **84** operates to generate electrical energy in a coil **85**. This electrical energy may be withdrawn from the terminals **86** for use as desired.

Every self-oscillating system may be regarded as embodying an amplification principle and a feedback principle by which energy is fed back from the output of the amplifier to its input. The apparatus with which the present invention deals is no exception, and so embodies an acoustic amplifier. Such an amplifier is schematically illustrated in Fig. 9 which shows a tube **90** having an open end and an end which is closed by a diaphragm **91** which in turn is caused to oscillate by application of the signal of an alternating source **92** to a coil **93** wound on a core **94**. A heater-cooler pair are provided between the diaphragm **91** where an approximate vibration node exists, and the location of the nearest vibration loop. The cooler may have substantially the same construction as in the other figures, i. e., metal strips **95** connected to external fins **97**. The same may be true of the heater but for illustrative purposes it is preferred to employ as a heater a screen or grid **96** of resistance wire which is heated by application thereto of the current of a battery **98** when and if a switch **99** is closed. Because the successive application of heat to the vibrating medium, in this case air, and extraction of heat from it as it vibrates through and past the heater and the cooler are in such phase as to tend to amplify the impressed acoustic oscillations, the apparatus acts as an acoustic amplifier for acoustic energy applied to its closed end by vibration of the diaphragm **91**. The apparatus of Fig. 9 may find utility as an electrically driven organ pipe.

Other applications of the foregoing principles will suggest themselves to those skilled in the art.

What is claimed is:

1. An acoustic wave system which comprises a vessel having fixed side walls and at least one fixed end wall and thus defining a constant volume, an elastic fluid wave-supporting medium contained within said vessel, a pair of closely spaced heat exchangers disposed within said vessel, means for applying heat to one of said exchangers, means for withdrawing heat from the other of said exchangers, and means for abstracting oscillatory energy from acoustic oscillations of said medium.

2. An acoustic wave system which comprises a vessel having fixed side walls and at least one fixed end wall and thus defining a constant volume, an elastic fluid medium contained within said vessel, said medium being free to undergo oscillatory flow in one direction within said vessel with a preassigned oscillation wavelength, a pair of heat exchangers disposed within said vessel, said exchangers being spaced apart in the direction of fluid flow by a small fraction of said oscillation wavelength, means for applying heat to one of said exchangers, means for withdrawing heat from the other of said exchangers, and means for abstracting oscillatory energy from acoustic oscillations of said medium.

3. An acoustic wave system which comprises a vessel having fixed side walls and at least one fixed end wall and thus defining a constant volume, an elastic fluid wave-supporting medium within said vessel, said medium being free to undergo oscillatory flow in one direction within said vessel with a determinable amplitude, a pair of closely spaced heat exchangers disposed within said vessel, the dimension of each of said exchangers in the direction of said fluid flow being approximately equal to said oscillation amplitude, means for applying heat to one of said exchangers, means for withdrawing heat from the other of said exchangers at a preassigned rate, whereby said oscillation amplitude is determined, and means for abstracting oscillatory energy from acoustic oscillations of said medium.

4. Apparatus as defined in claim 3 wherein at least one of said exchangers comprises a plurality of strips which are equally spaced apart in a direction normal to said fluid flow and wherein said strip spacing is related to the specific heat, the density and the thermal conductivity, respectively, of the fluid medium and to the oscillation period in accordance with the following formula:

$$T=\frac{cdl^2}{2k}$$

where

T=the oscillation period
c=the mean specific heat of the medium
d=the density of the medium
l=the spacing between the strips
k=the thermal conductivity of the medium

5. An acoustic wave system which comprises a vessel having fixed side walls and at least one fixed end wall and thus defining a constant volume, an elastic fluid medium contained within said vessel, said medium being free to undergo compressional vibrations and so to have standing waves established therein, said waves being characterized by a velocity node at one part of said vessel and by a velocity loop at another part of said vessel, a pair of closely spaced heat exchangers disposed within said vessel, means for applying heat to one of said exchangers, means for withdrawing heat from the other of said exchangers, and means for abstracting oscillatory energy from acoustic oscillations of said medium.

6. Apparatus as defined in claim 5 wherein the heat exchangers are located between a velocity node and a velocity loop for the acoustic oscillations.

7. Apparatus as defined in claim 5 wherein the heat exchangers are located substantially midway between a velocity node and a velocity loop for acoustic oscillations.

8. Apparatus as defined in claim 5 wherein the heat exchangers are located with the hot exchanger on that side of their midpoint which is nearest to the velocity node and with the cold exchanger on that side of their midpoint which is nearest the velocity loop.

9. A source of oscillatory energy which comprises a hollow resonator having at least one closed end, an elastic fluid medium within said resonator which is capable of supporting standing compression waves of wavelength and frequency determined by the dimensions of said resonator, said waves being characterized by a node portion of maximum oscillatory pressure and a loop portion of maximum oscillatory displacement and separated by substantially one quarter wavelength from said node portion, means for withdrawing heat from said fluid medium at a point approximately midway between said node portion and said loop portion, means for applying heat to

said fluid medium at a point between said node portion and the location of said heat-withdrawing means and closely adjacent to said heat withdrawing means, and means for abstracting a portion of the oscillatory energy of said compression waves.

10. Apparatus as defined in claim 9 wherein said hollow resonator is a rigid cylinder of length at least several times its diameter.

11. Apparatus as defined in claim 9 wherein said hollow resonator comprises a cylindrical body of rigid material having at one end thereof a cylindrical extension of expansible material and at the other end thereof a bulbous enlargement.

12. Apparatus as defined in claim 9 wherein said hollow resonator comprises a first cylinder of rigid material of length at least several times its diameter, a second cylinder of equal or greater length and less diameter disposed within and coaxially with said first cylinder, and a ring coupling similarly located ends of said cylinders thereby to define a cylindrical annular chamber for containing the working fluid medium.

13. Apparatus as defined in claim 9 wherein the elastic fluid medium is a gas.

14. Apparatus as defined in claim 9 wherein the elastic fluid medium is a mixture of gases of different atomic weights, the proportions of the several components of said mixture being selected to adjust the vibratory energy to a desired frequency.

15. Apparatus as defined in claim 9 wherein the elastic fluid medium is a vapor, and wherein a supply of the liquid of said vapor is provided within said resonator to ensure a sufficiency of said vapor.

16. Apparatus as defined in claim 9 wherein the combined axial depths of the heat-applying means and the heat-withdrawing means are substantially equal to the peak-to-peak excursion of molecules of the fluid medium at the location of said two means in the course of standing wave vibrations of said medium within said resonator.

17. An oscillatory heat engine which comprises a rigid hollow cylinder of length at least several times its diameter, a fixed closure at each end of said cylinder, a gas filling the interior of said cylinder, a permeable cooler member mounted in said cylinder substantially midway between one end of said cylinder and its midpoint, a permeable heater member mounted in said cylinder between said cooler member and said end of said cylinder and in close proximity to said cooler member, means for applying heat to said heater member, and means for withdrawing heat from said cooler member, whereby the gas column contained in said cylinder is set into longitudinal vibration, and means for utilizing the energy of vibration of said gas column.

18. An acoustic wave generator which comprises a tubular vessel having a fixed closed end and an open end and defining a substantially constant volume, an elastic fluid wave-supporting medium contained within said vessel and substantially filling said volume, a first heat exchanger disposed within said vessel and located substantially midway between its ends, means for abstracting heat from said first exchanger, a second heat exchanger disposed between the closed end of said vessel and said first heat exchanger and closely adjacent said first heat exchanger, and means for applying heat to said second exchanger, whereby acoustic vibrations are maintained within said vessel and are communicated to the external atmosphere by way of said open end.

19. An acoustic amplifier which comprises a tubular vessel having a fixed closed end and an open end and defining a substantially constant volume, an elastic fluid wave-supporting medium contained within said vessel and substantially filling said volume, a first heat exchanger disposed within said vessel and located between its ends, means for abstracting heat from said first exchanger, a second heat exchanger disposed between the closed end of said vessel and said first heat exchanger and closely adjacent said first heat exchanger, means for applying heat to said second exchanger, a source of a signal of a frequency to which the fluid medium contained within said vessel is resonant, and means for applying energy of said source as an oscillatory pressure to said medium by way of said closed end, whereby acoustic vibrations at said frequency are maintained and amplified within said vessel, and whereby said amplified vibrations are communicated to the external atmosphere by way of said open end.

20. A source of oscillatory energy which comprises two hollow tubular resonators, each having a completely closed end and a partially open end, an elastic fluid medium within each resonator which is capable of supporting standing compression waves of wavelength and frequency determined by the dimensions of said resonator, said waves being characterized by a node portion of maximum oscillatory pressure and a loop portion of maximum oscillatory displacement and separated by substantially one quarter wavelength from said node portion, means for applying heat to the fluid medium of each resonator at a point approximately midway between said node portion and said loop portion, means for withdrawing heat from the fluid medium of each resonator from a point between said loop portion and the location of said heat-applying means and closely adjacent to said heat-applying means, means for abstracting a portion of the oscillatory energy of the compression waves of each resonator, and a port interconnecting the partially open ends of said resonators, thereby to equalize the pressures within said resonators at their partially open ends and so to establish a pressure node at the midpoint of the system.

21. Apparatus as defined in claim 20 wherein said resonators are of like dimensions and wherein the fluid media contained therein are of like properties.

22. Apparatus as defined in claim 20 wherein said resonators are mounted on a common axis with their partially open ends adjoining one another.

23. In combination with apparatus as defined in claim 22, a source of heat common to the heat-applying means of said two resonators.

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