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PIEZOELECTRIC TRANSFORMER

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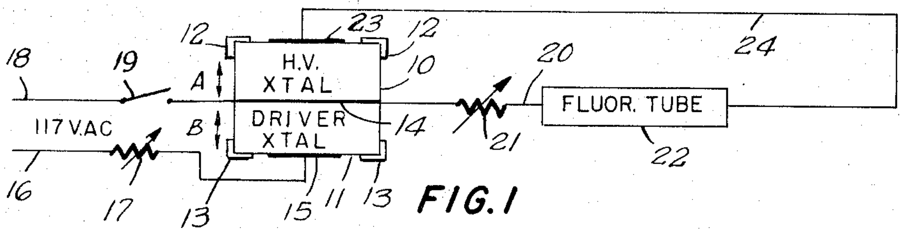

FIG. 1

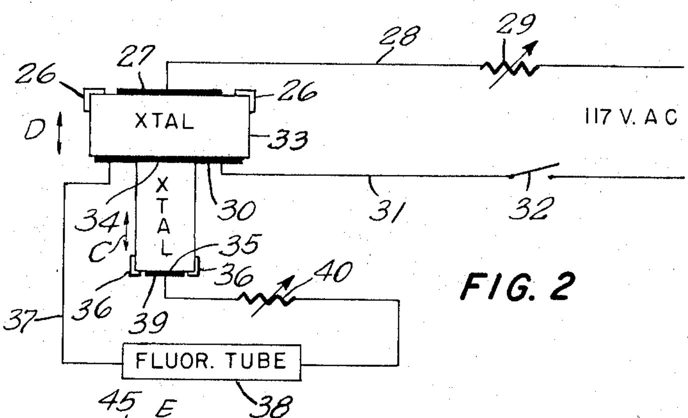

FIG. 2

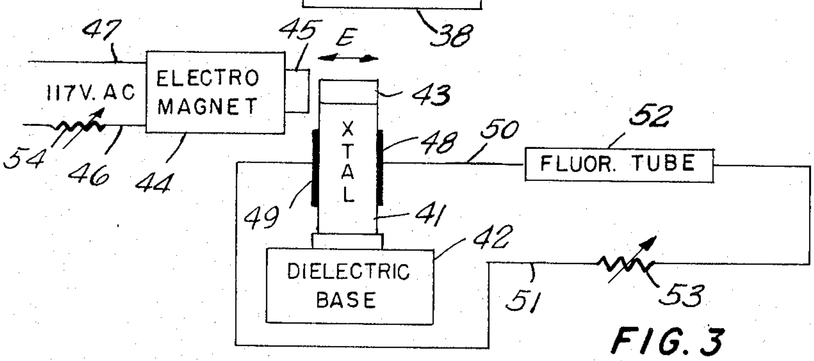

FIG. 3

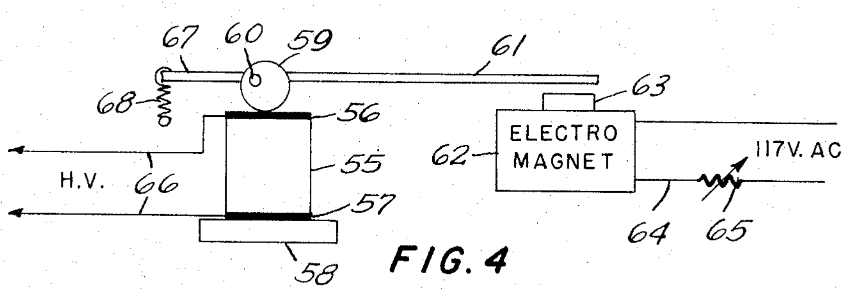

FIG. 4

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PIEZOELECTRIC TRANSFORMER

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This invention relates to electrical power systems, and more particularly to circuit means wherein piezoelectric transducer means are employed for generating and transforming electrical currents.

One of the characteristics of piezoelectric devices is that they are capable of developing an electrical potential in response to physical deformation by bending, twisting or squeezing.

Conversely, they are also capable of directly converting electrical energy into mechanical force represented by such deformation.

Devices of this type are known wherein a mechanical force directly applied to produce repeated deformation of a piezoelectric element to produce sustained pulsating electrical currents.

Present day advances in the art have reached the point where piezoelectric elements have been developed which are capable of generating voltages well in excess of those at which electric power is normally supplied to residential and commercial users.

It has been found that piezoelectricity can be artificially induced in certain synthetic, polycrystalline, ceramic materials, such as barium titanate, lead metaniobates, and lead zirconate-lead titanates. The last named of these materials is capable of generating potentials in excess of 20,000 volts.

While it is true that small, so-called "glow" lights in which an inert gas, such as neon, is ionized to provide luminescence, can be directly operated by commercially supplied power of 110 volts or less, such operation is possible because the electrodes are closely spaced a fraction of an inch apart.

However, no method is known prior to this invention for directly operating from a commercial power source, fluorescent lighting fixtures of the type wherein the gas contained within an envelope is to be ionized by electrodes which may be spaced several feet apart. These fixtures have, in the past, usually required some form of transformer means to provide a sufficiently high voltage to accomplish the initial ionization of the gas within the element, together with a mechanical switching means for temporarily operating the electrodes as heaters to warm up the gas.

It is, therefore, an object of this invention to provide a power supply having a voltage sufficient to operate devices of the fluorescent tube type, without requiring a starter to initiate ionization of the gases within the tubing and which any mechanical switches or ballast means is connected in the circuit during operation.

Other objects and advantages will be apparent to those skilled in the art after reading the attached specification in connection with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a circuit in which piezoelectric transducer means are employed in accordance with the teachings of this invention to supply high voltage to a load such as a fluorescent light from a commercially available low voltage source;

FIG. 2 is a schematic diagram of a modified form of piezoelectric transducer power converter;

FIG. 3 is a schematic diagram of still another piezoelectric transducer means for supplying a high voltage load from a low voltage source; and

FIG. 4 is a schematic diagram of a still further modified form of piezoelectric transducer transformer means for supplying a high voltage load from a low voltage source.

In the embodiment shown in FIG. 1, a first piezoelectric transducer element is indicated generally by the numeral **10**, this element being generally elongated and capable of generating an electrical potential in response to a flexural deformation, or bending, transversely with respect to its length, as indicated by the arrow A.

A second piezoelectric transducer element is indicated generally by the numeral **11** and is capable, in response to the application of an electrical potential, of flexural deformation, or bending, transversely with respect to its length as indicated by the arrow B.

Means is also provided, as will hereinafter be described, whereby the transducer element **11** is mechanically coupled with the transducer element **10**, whereby, when an electrical potential is applied to the element **11**, the resultant deformation of this element will be transmitted to the transducer element **10**, causing this element to generate an electrical output having a different potential than that applied to the element **11**.

A preferred manner in which this mechanical coupling may be accomplished is to provide mountings, such as the L-shaped spring clips **12** and **13**, at the outside end corners of the respective transducer unit so as to urge them in to abutting side by side relationship with a thin flexible contact strip **14** interposed between them. Flexural deformation, or vibration, of one crystal will thus be transmitted directly to the other crystal.

In certain cases, it may be desirable, in order to enhance the degree of mechanical coupling, to apply a thin coating of adhesive, such as an epoxy resin, between the adjacent sides of the crystals **10** and **11** and the common contact strip **14**. This is possible because the extent of bending and relative slippage between the crystals is quite minute.

Another contact strip **15** is secured to the other face of the transducer **11** which, in turn, is connected by lead **16**, through a variable resistor **17** to one side of a conventional source of electric power (not shown) such as a usual 110 volt AC supply.

One end of the common contact **14** is connected by a lead **18** through a switch **19** to the other side of the power supply.

The other end of the contact **14** is connected by a lead **20**, through a variable resistor **21** to one of the electrodes of a high voltage load such as a conventional fluorescent tube light **22**, the interior of which contains an ionizable gas such as neon or the like.

The transducer **10** is also provided with another contact **23** connected to the side opposite to that of the common contact **14**, and contact **23** is connected by lead **24** with the other electrode of the fluorescent tube **22**.

The principal criterion for the selection of the piezoelectric devices **10** and **11** is that the operating voltage of the element **10** should be at least equal to and preferably somewhat higher than the voltage sufficient to ionize the gas within the fluorescent tube **22** at normal temperatures. The synthetic polycrystalline ceramics, such as lead zirconate-lead titanate materials fulfill this condition. This voltage will, of course, depend upon the nature of the gas and the distance between the electrodes in the tube.

The principal characteristic of the piezoelectric element **11**, or driver crystal, is that it be capable of absorbing the current required at normal supply voltages, such as 110 volts or 220 volts, to be capable of driving the element **10**. The driver crystal will, of course, operate most efficiently if it is designed to resonate at, or near, the frequency of the power supply.

In operation, when switch **19** is closed to establish the circuit between the power supply and the contacts **14** and **15**, the transducer element **11** will undergo reciprocatory flexural deformation, or bending in the direction transverse to its length at a frequency corresponding to the frequency of the current supply. The voltage for the element **11** can be regulated by the resistor **17**.

Since the mountings **12** and **13** tend to maintain the two transducer elements **10** and **11** into intimate side by side abutting relationship and since the two elements are restrained only at their ends, any deformation of the element **11** will be transmitted to the element **10**, thus generating an output voltage in the leads **20** and **24**, whose frequency will correspond to that of the frequency of the vibration of element **11**. However, the voltage generated by crystal **10** will be high enough to ionize the gas in the fluorescent tube **22** directly at normal temperature.

In the modification shown in FIG. 2, a high voltage piezoelectric transducer is indicated by the numeral **25**, but, in this case, it is adapted to generate high voltage electrical energy in response to compression and expansion in the direction of the axis indicated by the arrow C.

Supported at its respective outside corners by mountings **26**, is a driver transducer **33**, having a contact **27** attached to one side connected by a lead **28** with one side of a commercial power supply (not shown), through a variable resistor **29**, if desired. The other side of the crystal **33** is provided with a contact **30** having a lead **31** for connection with the other side of the power supply and provided with a switch **32**.

The driving crystal is shown as generally elongated in form, and may take any appropriate shape with the proviso that its characteristic is such that when an electrical potential is applied, the crystal will be deformed by reciprocatory lateral bending in a direction indicated by the arrow D, as was the case with crystal **11** in FIG. 1.

One end **34** of the high voltage crystal **25** abuts against the contact **30** at the mid point of crystal **33**, while the other end is provided with a contact **35**, and is secured in position by means of the mountings **36**.

Common contact **30** acts also as one of the contacts for crystal **25** and is connected by lead **37** to one side of a high voltage load, which may be one of the electrodes of a fluorescent tube **38** similar to the device **22** shown in FIG. 1. The other contact **35** is connected by lead **39** through a variable resistor **40** to the other electrodes of the device **38**.

In operation, the driver crystal **33** performs in the same manner as the crystal **11** by vibrating from side to side at its mid point in response to the alternating changes in the polarity of the potential supplied by the electrical source, and in doing so, will alternately compress and relieve the strain on the driven crystal **25**.

Consequently, each compression of the driven crystal will produce a high voltage electrical charge across the electrodes of the load **38** and upon release, the driven crystal will expand to produce a similar charge of opposite polarity, thus maintaining ionization of the gas within the tube sufficient to maintain it lighted.

In the modification shown in FIG. 3, an elongated high voltage piezoelectric crystal **41** is firmly secured at one end with an adhesive such as an epoxy resin, or other suitable means, to a solid base **42**.

This crystal should be of the type which is capable of generating electricity by bending. The free end of the crystal is provided with a cap **43** of some suitable paramagnetic material, so that when a magnetic field which fluctuates in a direction transverse to the axis of the crystal is applied to the cap, the free end of the crystal will be induced to move in the direction indicated by the arrow E.

One method of providing such a field is to mount an electromagnet **44** so that the axis of its core **45** is positioned transversely with respect to the axis of the crystal with one end of the core being positioned closely adjacent the cap **43**, the gap between them being only so much as is necessary to allow for the vibration of the cap.

Obviously, when the leads **46** and **47** of the electromagnet are connected to a commercial source of alternating current (not shown), the cap **43** will be alternately attracted and repelled at a rate corresponding to the frequency of the power supply, thus bending the crystal **41** in alternate directions to generate a high voltage alternating current, whose frequency will also correspond with that of the power supply.

This current may be collected by means of contacts **48** and **49** attached to opposite sides of the crystal which, in turn, are connected to the leads **50** and **51**, these leads being connected to the respective electrodes of a high voltage load such as the fluorescent lamp **52**. As in the modifications previously described, the gas within such a tube can be ionized directly without requiring a starter, or ballast means.

If desired, the voltage supply from the crystal may be regulated as by means of the resistor **53**, or the voltage generated by the crystal may also be controlled by varying the intensity of the magnetic field of the electromagnet **44**, such as by regulating the voltage supplied thereto by means of a resistor **54** inserted in the lead **46** from the commercial power supply.

Still another modified form of the invention is shown in FIG. 4. In this form of device, the piezoelectric element **55** is of the type which is capable of generating a current when compressed or expanded and is provided with spaced contacts **56** and **57** at its respective ends.

One end of the crystal is mounted on a fixed base **58**, while a variable compressive force is applied at the other end by a mechanism which may include a cam device, such as the roller **59**, mounted for oscillatory movement about the eccentrically disposed pivot **60**. A laterally extending element **61**, secured to the roller, provides an armature at its outer end for an electromagnet **62** placed so that its pole piece **63** is closely spaced from one side of the element **61**.

It will be seen that when the electromagnet is energized through leads **64** by a suitable commercial source of electrical energy, the element **61** will be attracted downwardly towards the pole piece **63** which movement will cause the roller cam member to compress the crystal **55** between itself and the fixed base. The amount of force exerted by the cam may be controlled by a variable resistor **65** placed in the supply line to the electromagnet. As in the case of the previous modifications, the contacts **56** and **57** are connected by leads **66** to whatever load is to be supplied by the crystal.

Extending rearwardly from the cam is another arm **67** to which may be connected a biasing means, such as the spring **68**, to return the cam to the unstressed position when the power supply to the electromagnet is cut off.

Furthermore, while only a single surge of power will be delivered by the crystal when the cam is moved to compress it and another surge of opposite polarity will be delivered upon release of the cam, it will be evident that a pulsating or alternating current may be supplied by the crystal if the electromagnet is driven by a pulsating or alternating current.

It will also be evident that while in the preferred embodiment of this modification, the crystal **55** would be of the lead zirconate-lead titanate high voltage type, it will be further evident that other types of crystals capable of generating a potential in response to the compression and expansion could also be used.

Having disclosed several forms in which the invention may be practised, it will be evident that further modifications and improvements may be made by one skilled in the art which would come within the scope of the annexed claims.

I claim:

1. In an electrical lighting system comprising an envelope containing an ionizable gas and a pair of spaced

electrodes for establishing an electrical path through said gas, a pair of piezoelectric transducer means each having a pair of opposed surfaces and capable of developing an electrical potential between said opposed surfaces in response to physical deformation and vice versa, means for establishing first circuit means including only the opposed surfaces of one of the transducer means and a source of alternating current for cyclically deforming said one transducer means, means for mounting said pair of transducer means for mechanically connecting said one transducer means with the other transducer means for deforming said other transducer means for creating alternating electrical potentials across the opposed surfaces of the other transducer means in response to said cyclical deforming of the one transducer means, and means for establishing second circuit means including only the opposed surfaces of the other transducer means with the spaced electrodes in said envelope.

2. The invention as defined in claim **1**, wherein said transducers comprise elongated elements arranged for flexural deformation.

3. The invention as defined in claim **1**, wherein said transducers comprise elongated elements, one of said transducers being arranged for flexural deformation, the other transducer being arranged for longitudinal deformation.

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