Jan. 7, 1964 R. L. GAMBLIN 3,117,256

ELECTROMECHANICAL TRANSDUCER

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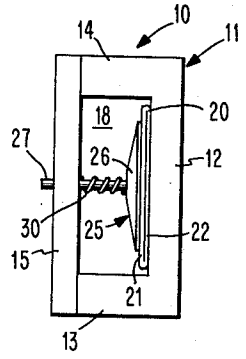



FIG. 1

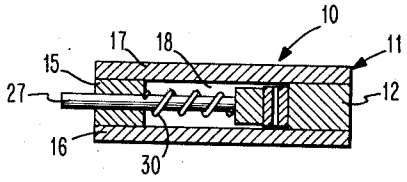



FIG. 2

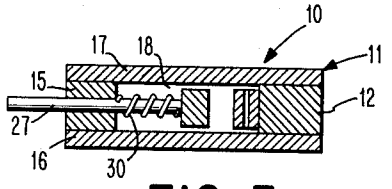



FIG. 3

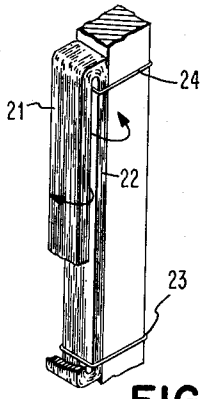



FIG. 4

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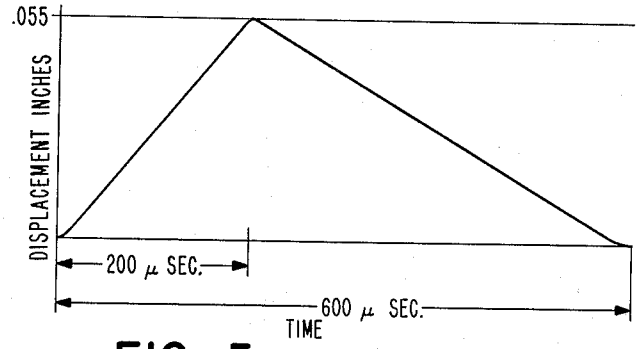



FIG. 5

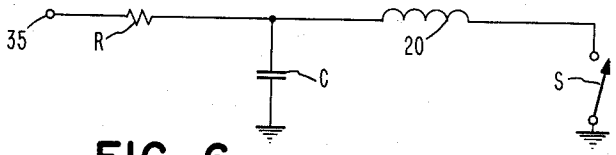



FIG. 6

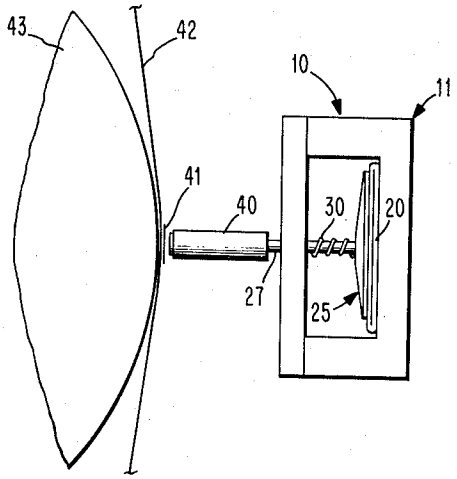



FIG. 7

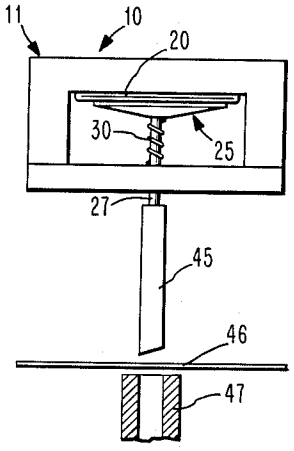



FIG. 8

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3,117,256

# ELECTROMECHANICAL TRANSDUCER

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Filed Jan. 3, 1961, Ser. No. 80,434
10 Claims. (Cl. 317—166)

This invention relates to electromechanical transducers and, more particularly, to an expanding coil type of electromechanical transducer.

In the present invention, electrical energy is converted to mechanical energy through the facility of an air cored coil having a particular configuration so as to produce very high accelerations. The mechanical energy is incorporated into a mechanical system to move an element or actuator.

Heretofore, electromechanical transducers usually utilized electromagnets or supported spiral wound coils. Electromagnets are inherently limited in speed of operation primarily because of the saturation characteristics of ferromagnetic materials. In an air cored coil, the efficiency of energy conversions increases as the amount of kinetic energy realized increases. The general objection to supported spiral coils is the lack of compactness, the lack of inherent resiliency in the direction of movement, they are of greater mass, and at least two coils are required.

This invention is particularly suited to be incorporated into selectively operable record punching and printing machines which are to operate at relatively high speeds.

Accordingly, a prime object of this invention is to provide an improved electromechanical transducer.

Another important object of the invention is to provide an improved electromechanical transducer which is capable of operating at very high speeds.

Still another object of the invention is to provide an improved electromechanical transducer which is very compact.

Yet another object of the invention is to provide an improved electromechanical transducer which is relatively inexpensive.

Another object of the invention is to provide an improved electromechanical transducer which is suited to be incorporated in a relatively high speed selectively operable punching machine.

It is also an object of the invention to provide an improved electromechanical transducer which is suited to be incorporated into a relatively high speed selectively operable printing machine.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a front elevational view of the improved electromechanical transducer;

FIG. 2 is an enlarged sectional view of the transducer shown in FIG. 1, the transducer as shown has just been energized and the front leg of the coil has been moved away from the back leg;

FIG. 3 is an enlarged sectional view of the transducer and is similar to FIG. 2; however, the impact member



has moved away from the front leg of the coil due to the force applied thereon by said front leg;

FIG. 4 is an enlarged perspective view of the coil showing the back leg tied or banded to the frame;

FIG. 5 is a schematic diagram of a displacement versus time curve for the impact member;

FIG. 6 is a schematic diagram illustrating the circuit for energizing the coil of the transducer;

FIG. 7 is a schematic showing of the transducer as incorporated in a selectively operable printing machine; and,

FIG. 8 is a schematic showing of the transducer as incorporated in a selectively operable punching machine.

Referring to FIG. 1, the invention is illustrated by way of example as an improved electromechanical transducer **10**. The transducer **10** includes a housing **11**, a coil **20**, an actuator **25** and spring **30**. The housing **11**, FIGS. 1 and 2, includes an upright U-shaped frame member **12** and a bridging member **15** which is connected to the ends of legs **13** and **14** of U-shaped member **12**. Front and back cover plates **16** and **17**, FIG. 2, are secured to members **12** and **15** so as to form an enclosure having a cavity **18**.

The coil **20**, FIG. 1 and 2, is an air cored coil of a particular configuration. The coil **20**, FIG. 4, is generally rectangular, and the winding depth should be small compared to coil length. The coil **20** is comprised of front and back legs **21** and **22**, each leg consisting of a plurality of long parallel conductors. Current flows through the conductors of the front leg **21** in one direction and through the conductors of leg **22** in an opposite direction. Accordingly, assuming a particular direction of current flow in the conductors of leg **21**, the conductors of leg **21** are then surrounded by a magnetic field having lines of force taking the form of circles with the conductors of the leg **21** as the axis. Likewise, with current flowing in the conductors of leg **22** in a direction opposite to the current flow in the conductors of leg **21**, the magnetic field developed by the current flow surrounds the conductors of leg **22** in a manner that the lines of force of the magnetic field are circles with the conductors of leg **22** as the axis.

The lines of force of the magnetic field surrounding the conductors of leg **21** are in an opposite direction to that of the lines of force of the circles surrounding the conductors of leg **22**. In FIG. 4, the lines of force encircling the conductors of leg **21** are shown to be clockwise while the lines of force encircling the conductors of leg **22** are shown to be counterclockwise. However, the lines of force of the two magnetic fields are in the same direction when passing through the air gap between the legs **21** and **22** of coil **20**. Since a net gradient of a magnetic field in a current carrying region causes a force, the legs **21** and **22** are urged away from each other when coil **20** is energized.

Coil **20** is placed in the cavity **18** so that the outer surface of leg **22** abuts against the inner surface of member **12**. The outer surface of the front leg **21** of coil **20** engages base **26** of the actuator or impact member **25**. A cylindrical member **27** is attached to and extends proudly from the base **26** to project through an aperture provided in the member **15**. The spring **30** embraces the member **27** in a manner that one end of the spring abuts against the inner surface of the member **15** while

the other end of the spring abuts against the base member 26. By this arrangement, the spring 30 holds the base member 26 against the leg 21 so that the coil 20 is held in place in the cavity 18 and functions to return the actuator 25 to the position shown in FIG. 1 after the same has been propelled forward in response to the coil 20 being energized as in FIG. 3.

The force upon the coil is proportional to the square of the current in the coil. The force is determined according to the formula:

$$F = M_0(NI)^2\frac{l}{b}$$

where:

$M_0$=effective permeability of the magnetic path for the lines of flux
$N$=number of turns in the coil
$I$=intensity of the current
$l$=length of the coil
$b$=width of the coil

It has been found that the efficiency is related to the resistivity, and mass density of the coil conductors and effective permeability of the flux path. Aluminum, copper and iron have been found to be suitable materials for coil conductors. In this example, the coil 20 consists of 100 turns of #36 aluminum wire coated with suitable insulating material. The coil weighs approximately .135 gram. The actuator 25 is made of aluminum and weighs approximately .120 gram. Spring 30 has a spring force sufficient to allow operation within a cycle of approximately 600 microseconds.

Coil 20 is selectively energized by being connected to a circuit as shown in FIG. 6. In FIG. 6, terminal 35 is adapted to be connected to a power supply having a constant D.C. voltage. The coil 20 is connected in series with a switch S and a resistor R; the switch S is connected to ground and the resistor R is connected to terminal 35. A storage capacitor C is connected in parallel with the coil 20 and is also connected to ground potential. With the switch S open, the power supply delivers a current to terminal 35 which flows through resistor R until the storage capacitor C becomes charged to a voltage equal to that of the power supply. When the storage capacitor C is fully charged, the circuit becomes static and no current flows until the switch S is closed. The coil 20 is selectively energized by closing the switch S. Upon closing the switch S, the charge on the storage capacitor C discharges through the coil 20 and the switch S. In this example, the power supply furnishes 500 volts and the storage capacitor is approximately 5 microfarads. Thyratrons have been found to be suitable elements for the switch S.

For the example given, with the storage capacitor C charged and switch S closed, the coil 20 is energized and the front leg 21 moves away from the rear leg 22, as seen in FIG. 2. The movement of the front leg 21 imparts momentum to the actuator 25 which continues to move, thereby compressing the spring 30, due to inertia, as seen in FIG. 3. The spring 30 then returns the actuator 25 to the position shown in FIG. 1. In this example, the cycle of operation is approximately 600 microseconds. The actuator 25 is propelled to its extreme forward position by means of the front leg 21 in approximately 200 microseconds and it is then subsequently returned by means of the spring 30, in approximately 400 microseconds. Total displacement of the actuator 25 in this example is approximately .055 inch. It was found that improved results were obtained when a band of wire such as bands 23 and 24 were utilized to tie the conductors of the back leg 22 in a group to the member 12. This constrains the leg 22 of the coil against movement for the full forward thrust.

In order to reduce wear of the coil 20, FIG. 4, the coil was soaked in a diluted adhesive, such as an adhesive



formulated from a base comprising oil and soluble elastomers. The adhesive does not tend to make the coil stiff, but does coat the individual conductors so as to reduce the wear of the conductors of the coil. Because there is some relative movement between the conductors of the coil due to the magnetic fields, there is a tendency for wear to take place. Another most effective means of reducing wear is to coat the actuator 25 and members 12, 15, 17 and 18 with a resilient plastic such as nylon or polytitrafluoroethylene and to wrap each leg of the coil 20 with a tough plastic such as polyester film which is coated with paraffin oil.

In FIG. 7, the electromechanical transducer 10 is shown as being incorporated in a selectively operable printing machine. A type element 40 is fixed to the end of member 27. An inked ribbon 41 is disposed adjacent the end of the type element 40. A sheet of paper 42 for receiving print impressions is disposed between the inked ribbon 41 and a platen 43. Upon energization of the coil 20, the type element 40 is projected forward as the actuator 25 is impacted by the front leg 21 to carry the ribbon 41 against the paper 42 and transfer a portion of the ink from the ribbon in the form of the character onto the paper 42.

In FIG. 8, the electromechanical transducer 10 is shown as being incorporated in a selectively operable record card punching machine. A punch element 45 is attached to the end of the member 27. A record card 46, which is to be punched, is disposed between the punch 45 and a die and stripper assembly 47. Upon energization of the coil 20, the actuator 25 is propelled so that the punch 45 punches the record card 46 and the spring 30 subsequently restores the punch.

Of course, the electromechanical transducer 10 may be used for a variety of other purposes such as an operator for a high speed relay or for a hydraulic valve.

From the foregoing, it is seen that the invention provides for an improved electromechanical transducer. The improved electromechanical transducer is operable at very high speeds and is particularly suited to be incorporated into selectively operable printing and punching machines.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An electromechanical transducer comprising: a rigid support, a reciprocally mounted actuator movable relative to said support, an air cored coil disposed between said rigid support and said actuator, said coil being substantially rectangular, and means biasing said actuator so that said air cored coil abuts said actuator and said rigid support.

2. An electromechanical transducer comprising: a rigid support, a reciprocally mounted actuator movable relative to said support, a coil having first and second legs with an air gap therebetween positioned between said actuator and rigid support so that said first leg faces said rigid support and said second leg faces said actuator, and means biasing said actuator so that said first leg is abutting against said rigid support under pressure and said second leg is engaged under pressure by said actuator.

3. An electromechanical transducer according to claim 2 wherein said biasing means is a spring.

4. An electromechanical transducer according to claim 2 wherein securing means secure said first leg of the coil to said rigid support.

5. An electromechanical transducer according to claim 2 wherein said coil is impregnated with an adhesive.

6. An electromechanical transducer as in claim 2 wherein said rigid support and said actuator are coated with a nonconducting tough plastic material.

7. An electromechanical transducer comprising: a

housing having at least one pair of opposite walls, a reciprocally mounted actuator having one portion disposed within said housing and another portion extending therefrom, a coil having first and second legs with an air gap therebetween disposed within said housing so that said first leg faces one of said opposite walls and said second leg faces said one portion of the actuator, and means biasing said actuator so that said one portion thereof abuts against said second leg and urges said first leg into contact with said one of said opposite walls.

8. An electromechanical transducer according to claim 7 wherein said biasing means comprises a spring engaging said one portion of the actuator and the other wall of



said opposite walls to urge the same into contact with said second leg of the coil.

9. An electromechanical transducer as in claim 7 further comprising a print element fixed to said another portion of the actuator extending from said housing.

10. An electromechanical transducer as in claim 7 further comprising a punch element fixed to said another portion of the actuator extending from said housing.

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