(No Model.)

3 Sheets—Sheet 1.

J. S. STONE.

RESONANT ELECTRIC CIRCUIT.

No. 577,214. Patented Feb. 16, 1897.

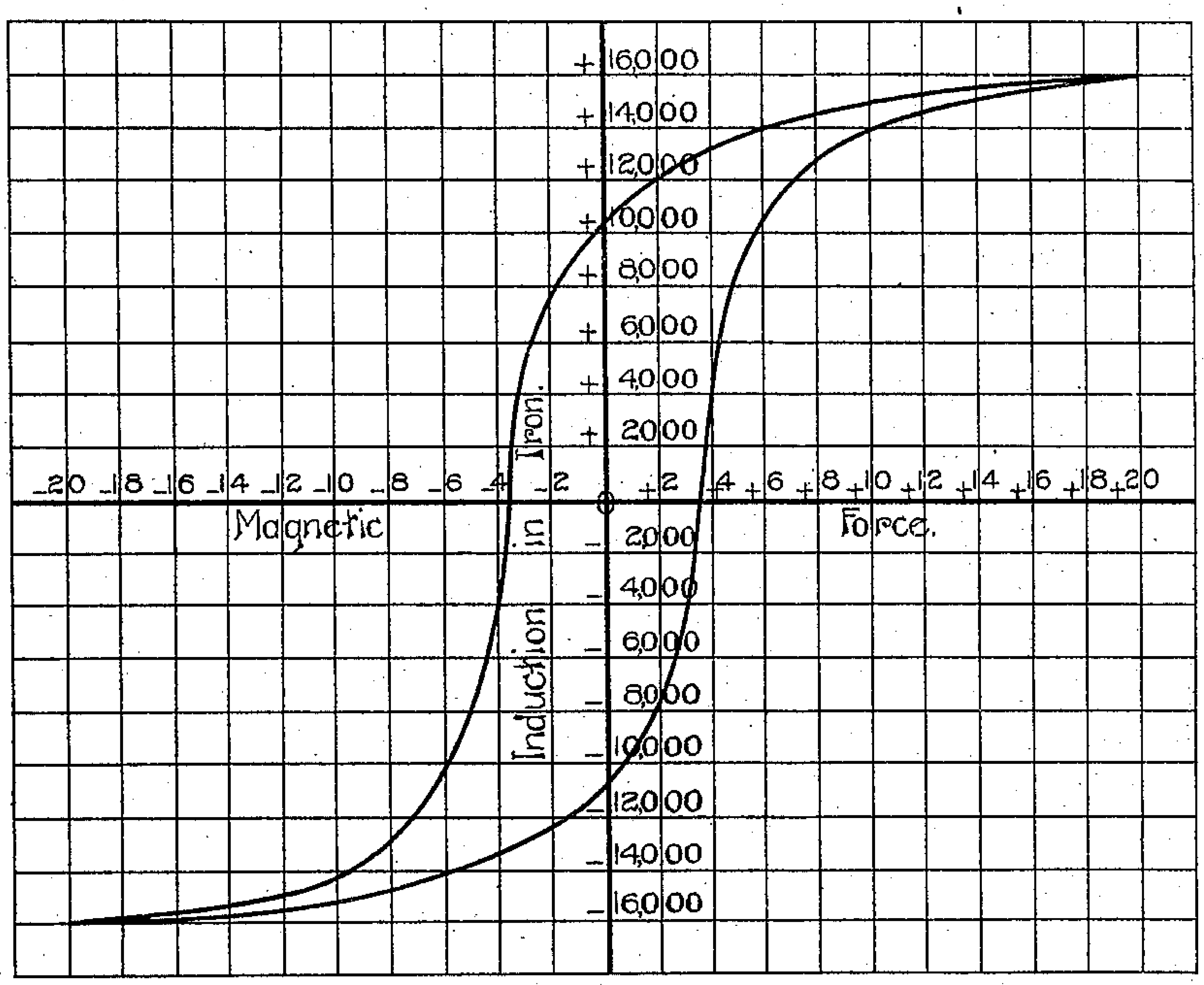

Fig. 1.

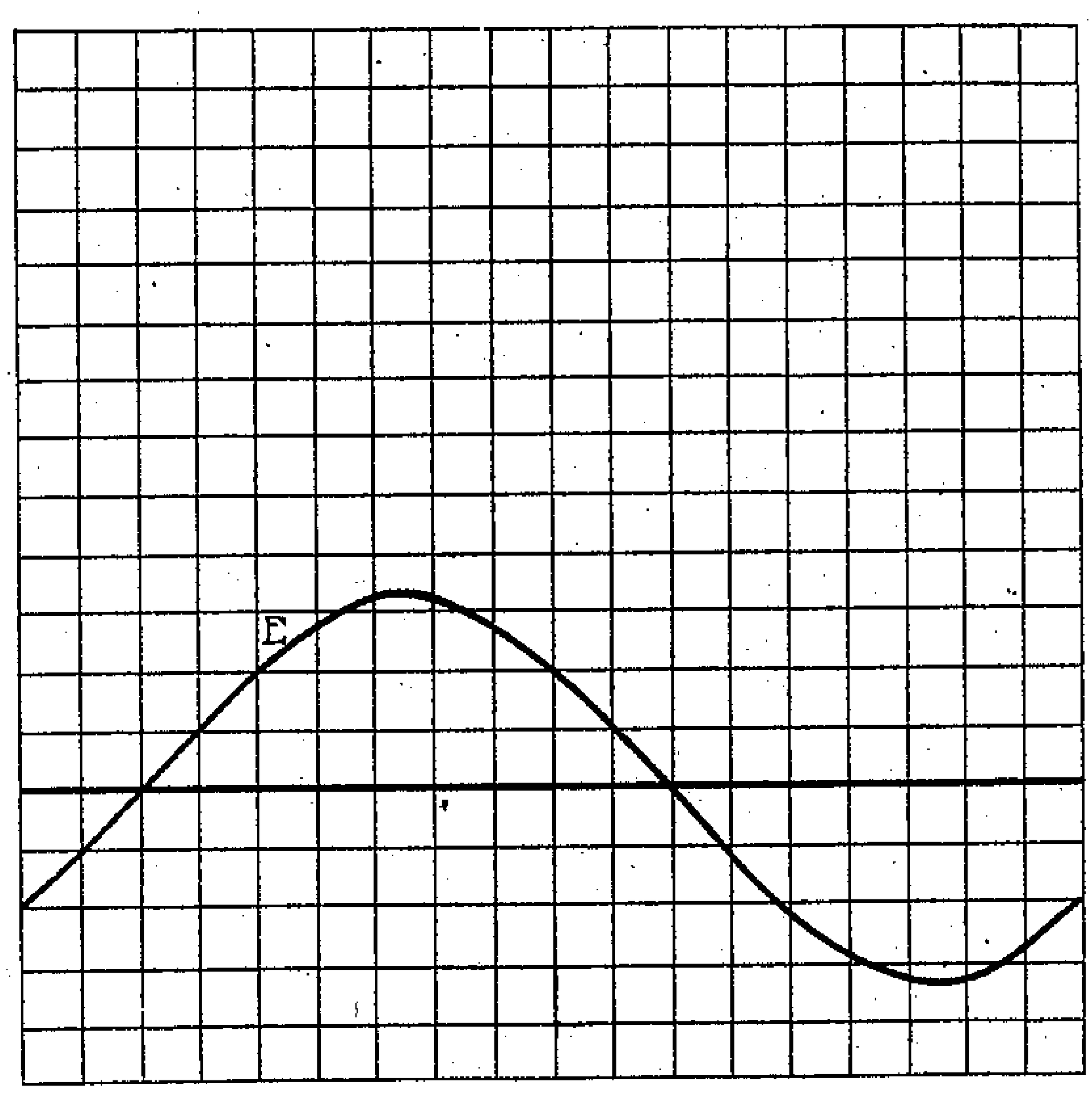

Fig 2.

Attest,

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(No Model.) 3 Sheets—Sheet 2.

J. S. STONE.

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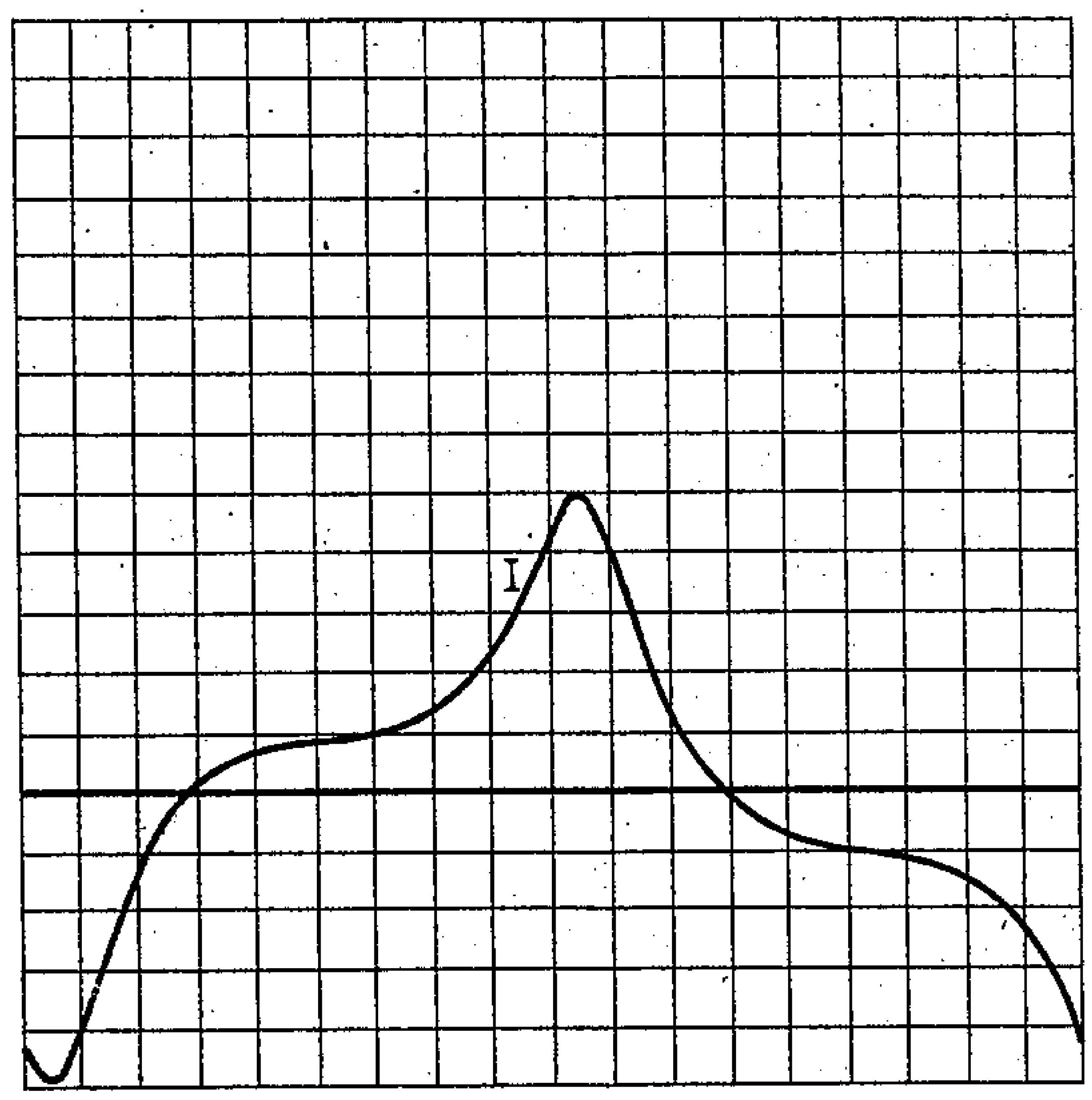

Fig. 3.

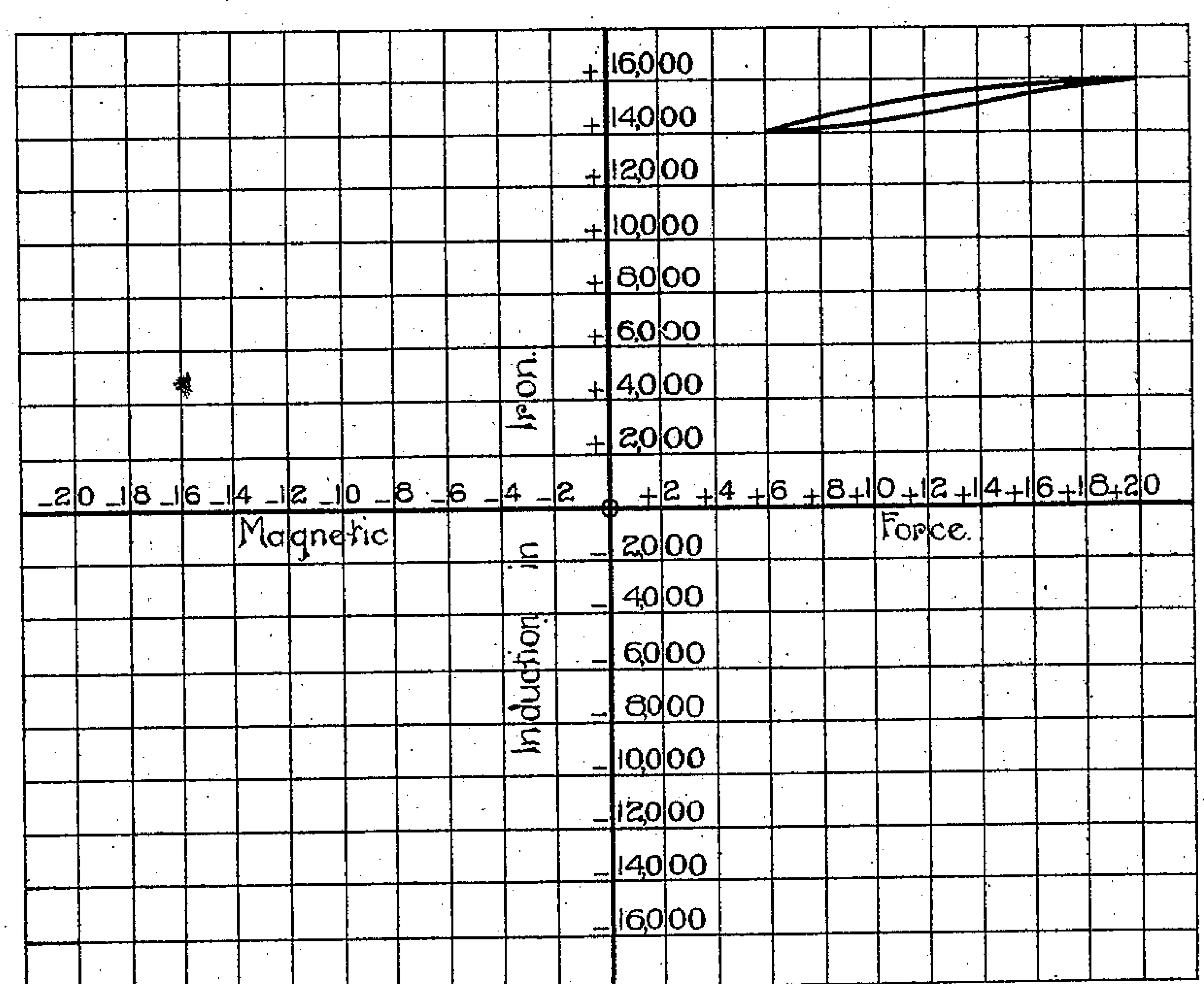

Fig. 4.

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Inventor,
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THE NORRIS PETERS CO. PHOTO-LITHO., WASHINGTON, D. C.

(No Model.) 3 Sheets—Sheet 3.

J. S. STONE.

RESONANT ELECTRIC CIRCUIT.

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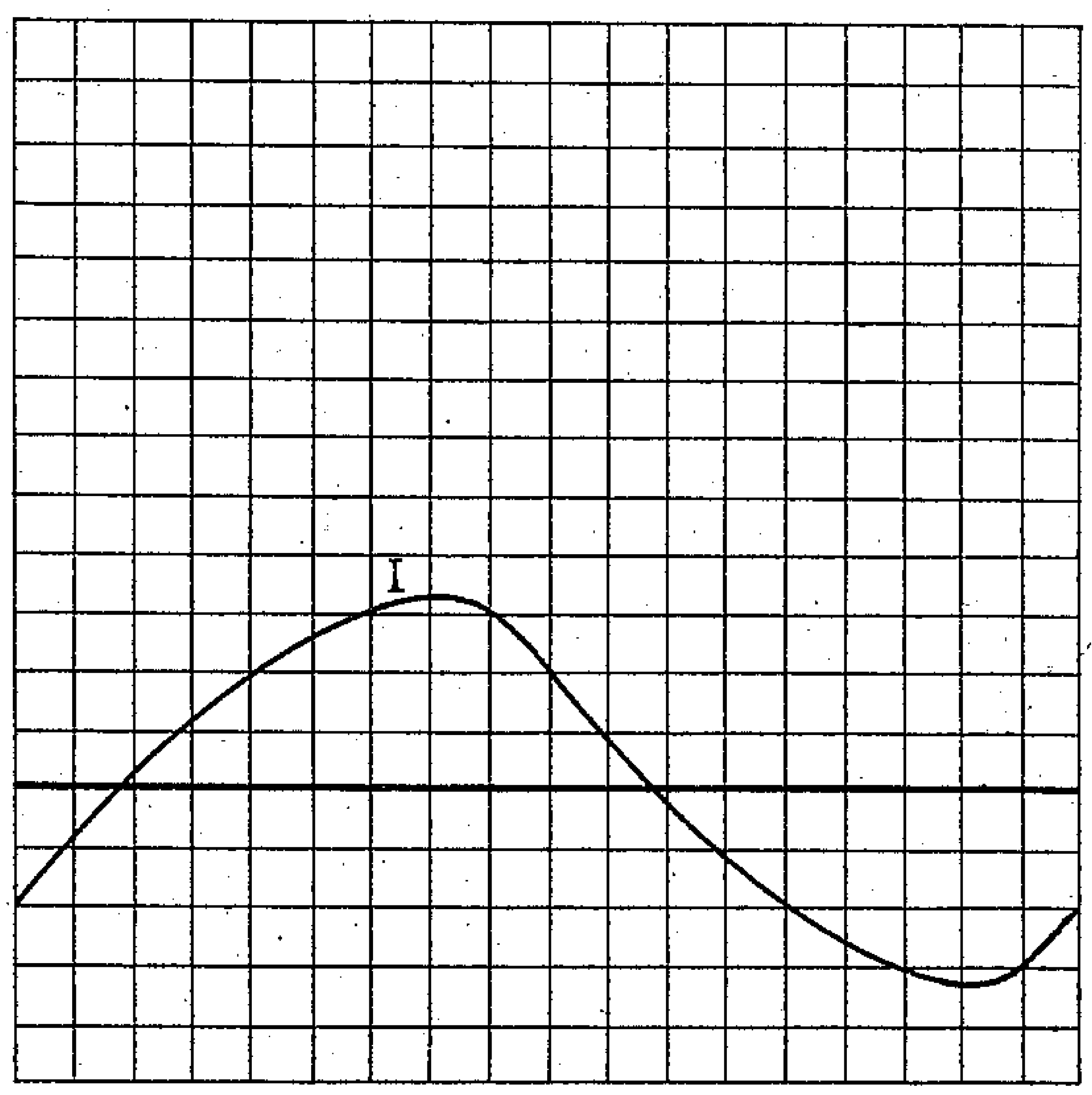


Fig 5.

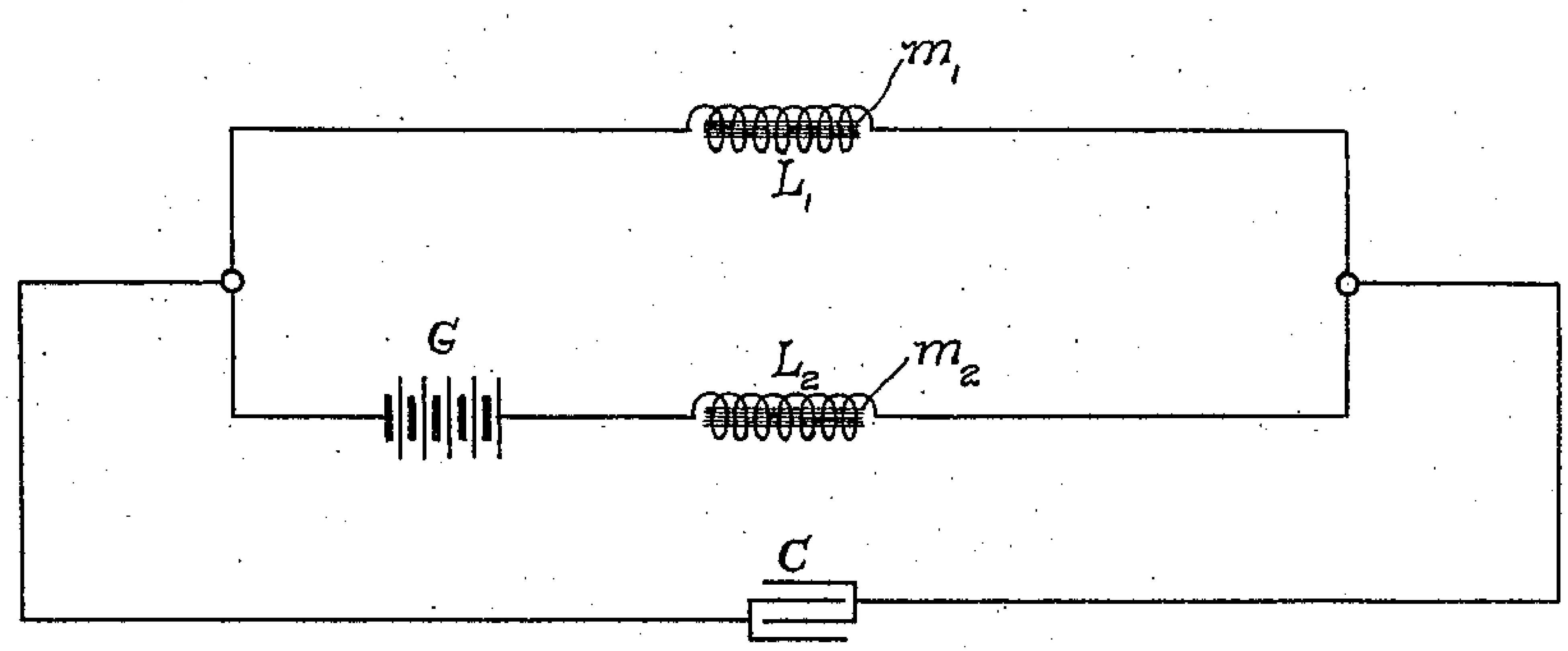
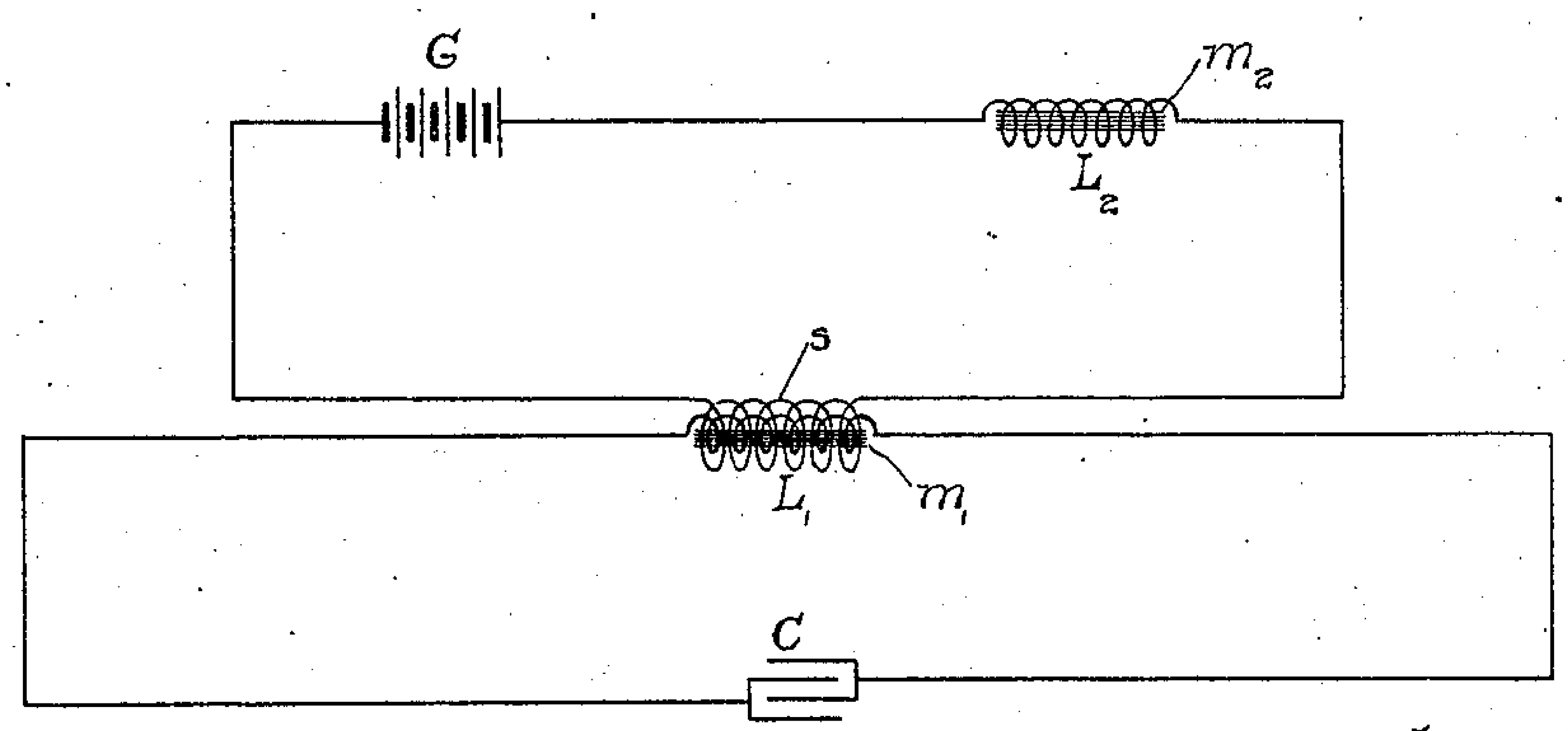


Fig 6.



Attest, Fig 7. Inventor,

W. W. Swan

Geo. Willis Pierce

John S. Stone

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

JOHN S. STONE, OF BOSTON, MASSACHUSETTS, ASSIGNOR TO THE AMERICAN BELL TELEPHONE COMPANY, OF SAME PLACE.

RESONANT ELECTRIC CIRCUIT.

SPECIFICATION forming part of Letters Patent No. 577,214, dated February 16, 1897.

Application filed September 10, 1896. Serial No. 605,368. (No model.)

To all whom it may concern:

Be it known that I, JOHN STONE STONE, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain Improvements in Resonant Electric Circuits, of which the following is a specification.

The invention relates to that class of resonant circuits which contain ferric inductance, *id est*, inductance resulting from the magnetization of paramagnetic materials, its object being to increase the selectivity of such circuits.

More specifically, the invention consists in initially or independently magnetizing the paramagnetic material which contributes to the inductance in the resonant circuit, and also in providing means whereby this independent magnetization may be supplied by an electric current.

In the drawings, Figures 1, 2, 3, 4, and 5 are diagrams illustrative of electrical phenomena upon which my invention is based, the first three being familiar diagrams taken from published papers on hysteresis. Figs. 6 and 7 are diagrams illustrating resonant circuits embodying my invention.

A resonant electric circuit may be defined as a circuit which presents a smaller impedance to alternating currents of a particular frequency than to alternating currents of any other frequency, thereby favoring the development in it of currents of that one particular frequency.

A typical resonant circuit consists of a coil having inductance connected in series with a condenser having electrostatic capacity. If such a circuit is so constructed that an alternating current may flow in it without magnetizing paramagnetic material, without inducing currents in neighboring circuits, and without producing displacement-currents in dielectrics which exhibit electrostatic hysteresis, the circuit will be found to respond most strongly to currents of a particular frequency, and its impedance to currents of that particular frequency will be equal to the ohmic resistance of the coil. Such a circuit is an ideal resonant circuit and will be highly selective if the coil be of low resistance and great inductance while the condenser is of small capacity.

By the term "selective" is meant that property which resonant circuits exhibit of responding more strongly to currents of one particular frequency than to those of any other frequency, and by "selectivity" reference is made to the degree to which they exhibit this selective property.

When resonant circuits are used in the arts for multiple and selective signaling and for other useful purposes, it is necessary that they be highly selective and that they respond to moderate-frequency currents. In order, however, that they may satisfy these conditions, the inductance-coil used must be of low resistance and large inductance—*id est*, it must have a large electromagnetic time-constant, while the condenser used must be of small capacity.

In the practical application of electricity up to the present time it has been the custom to construct inductance-coils which are to have a large electromagnetic time-constant by winding many turns of fine copper wire on a core of soft iron. By this construction a coil of large time-constant may be obtained at a moderate expense and in a convenient size. If it were attempted to construct a coil of equal electromagnetic time-constant without the use of a core of paramagnetic material, such as soft iron, it would be found necessary to use an enormously greater number of turns of a very much larger wire, the dimensions of the coil, its weight, and the expense of constructing it being more than proportionately enhanced. In fact it is quite impracticable to construct a coil without an iron core which shall have as great an electromagnetic time-constant as that possessed by many iron-core coils at present in constant use in the practical applications of electricity. When, however, inductance-coils with iron core form part of a resonant circuit, it is in general observed that they exert a very detrimental effect upon the selectivity of the circuit, preventing the circuit from exhibiting a sharply-defined minimum of impedance for one particular frequency of current and causing the minimum impedance to be far in excess of the ohmic resistance of the conductive part of the circuit. The same effect will be observed when the inductance-coils in resonant circuits are wound upon cores of paramagnetic materials other than iron. This detrimental effect produced by the presence of paramagnetic materials in the cores of inductance-coils in resonant circuits may be attributed to the property of hysteresis, which these materials possess to a marked degree, to the Foucault currents which are induced in them when an alternating current flows in the circuit, and to the fact that the permeability of these magnetic materials is not independent of the intensity of the induction through them. The reason for this conclusion is better understood by having reference to the diagram Figs. 1, 2, and 3, which accompany and form a part of this specification.

Fig. 1 is a normal magnetization-curve of a sample of soft iron and exhibits the relation which exists at any moment between the magnetic induction in a closed magnetic circuit of the soft iron and the magnetomotive force which engenders it. The diagram represents this relation for each moment of time during a complete cycle when the magnetic induction varies periodically between the values +16000 and −16000. In this curve the abscissæ represent the magneto-motive force and the ordinates represent the corresponding or resulting magnetic induction.

Fig. 2 is a curve representing a simple harmonic alternating electromotive force, the ordinates representing electromotive forces and the abscissæ times.

Fig. 3 represents a complex harmonic alternating current, the ordinates representing intensities of current and the abscissæ times.

These three diagrams, when considered together, illustrate the distortion of an alternating current which may result from the presence of ferric inductance in the circuit traversed by the current, for if the simple harmonic electromotive force represented in Fig. 2 be impressed upon a coil of large time-constant wound upon the core of soft iron whose magnetic properties are represented in Fig. 1, and if the magnetic induction thereby engendered in the soft-iron core vary periodically between the limits +16,000 and −16,000, as represented in Fig. 1, then the resulting current will be that shown in Fig. 3, instead of being a simple harmonic function of the time, as would be the case were the core of paramagnetic material not present. With such a distortion of the current attributable to the paramagnetic core the disturbing effects of such cores upon the phenomenon of electrical resonance is readily appreciated. Reasoning upon this hypothesis I have been led to believe that the detrimental effects exerted by paramagnetic materials contributing to the inductance of resonant circuits might be materially reduced by initially or independently magnetizing the said magnetic material.

In illustrating the reaction upon an alternating current which may result from the presence in the circuit traversed by the current of an inductance-coil with an initially or independently magnetized core of soft iron, reference will be had to the diagram Figs. 1, 2, 4, and 5.

Figs. 1 and 2 have already been described.

Fig. 4 is a normal magnetization-curve for a sample of soft iron initially magnetized to an induction of fifteen thousand, and it shows the relation which exists at any moment between the magnetomotive force in a closed magnetic circuit of the soft iron and the resulting magnetic induction, such relation being exhibited for each instant during a complete cycle when the magnetic induction varies periodically between the values fourteen thousand and sixteen thousand.

Fig. 5 is a curve representing an alternating current which is practically a simple harmonic current, but which differs slightly in its form from the simple sign-wave. In this diagram, as in Fig. 3, the ordinates represent intensities of current and the abscissæ times.

If the simple harmonic electromotive force represented in Fig. 2 be impressed upon a coil of a large number of turns and of small resistance wound about the initially-magnetized core of soft iron whose magnetic properties are those shown in Fig. 4, and if the resulting magnetic induction in the core vary periodically between the limits sixteen thousand and fourteen thousand, as shown in Fig. 4, the current which will result will be that shown in Fig. 5. This current is practically a simple harmonic current, and is therefore practically the same current as would be developed in the circuit by the electromotive force were the inductance not ferric. The inductance due to such an independently-magnetized core of paramagnetic material should therefore be expected not to interfere with the phenomena of resonance, but under favorable conditions to behave much like nonferric inductances when placed in resonant circuits. Experiments have proved this conclusion to be correct, and as a result of this discovery I am enabled to use and have used inductance-coils with cores of magnetic materials in resonant circuits for practical purposes, thereby obtaining the important advantages which I have already stated that such coils possess in point of compactness and economy.

Several ways of accomplishing the initial magnetization of the cores of the inductance-coils in resonant circuits will suggest themselves to any one skilled in the art; but my favorite method of accomplishing this result is by means of an electric current. More specifically it consists in including the coils whose cores of magnetic materials it is desired to magnetize in a closed conductive circuit containing a source of direct current. Such organizations are shown diagrammatically in Figs. 6 and 7, in which diagrams G is a generator of direct current, L′ and L^2 are inductance-coils having cores of paramagnetic material m' and m^2, respectively, and C is a condenser.

In the operation of the organization shown in Fig. 6 the direct current from the source G passes in series through the coils L′ and L^2, producing an initial magnetization in their cores, upon which magnetization an alternating current circulating in the resonant circuit will superinduce an alternating magnetization.

In the organization shown in Fig. 7 the inductance-coil L′, which supplies the necessary inductance for the resonant circuit, is provided with an extra helix *s*, which helix is included in a local circuit supplied with direct current from the generator G. The direct current, circulating in the helix *s* of the inductance-coil L′ causes a direct magnetization of the core m' of that coil, and any alternating current which may be caused to flow in the resonant circuit will superimpose an alternating magnetization upon the initial or direct magnetization.

The inductance-coil L^2 is included in the circuit of the generator G and helix *s*, in order that by virtue of its impedance it may render that circuit opaque to alternating currents such as may circulate in the resonant circuit including the coil L′ and so minimize the inductive reaction of the helix *s* upon the resonant circuit.

In carrying out this invention none of the precautions usually taken to prevent the development of Foucault currents should be neglected, and even greater precaution should be taken for the prevention of such parasitic currents.

I claim—

1. A resonant electric circuit containing inductance resulting from the magnetization of independently-magnetized paramagnetic material.

2. A resonant electric circuit containing inductance resulting from the magnetization of paramagnetic material independently magnetized by means of an electric current.

3. In a resonant electric circuit containing an inductance-coil having a core of paramagnetic material, an associated conductive circuit including serially a source of direct current and the said inductance-coil, substantially as described.

4. A resonant electric circuit containing a closed conductive circuit including serially a source of direct current and inductance-coils having a paramagnetic core, substantially as described.

JOHN S. STONE.

Witnesses:
W. W. SWAN,
GEO. WILLIS PIERCE.