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TUNING FORK GENERATOR

Filed June 16, 1928

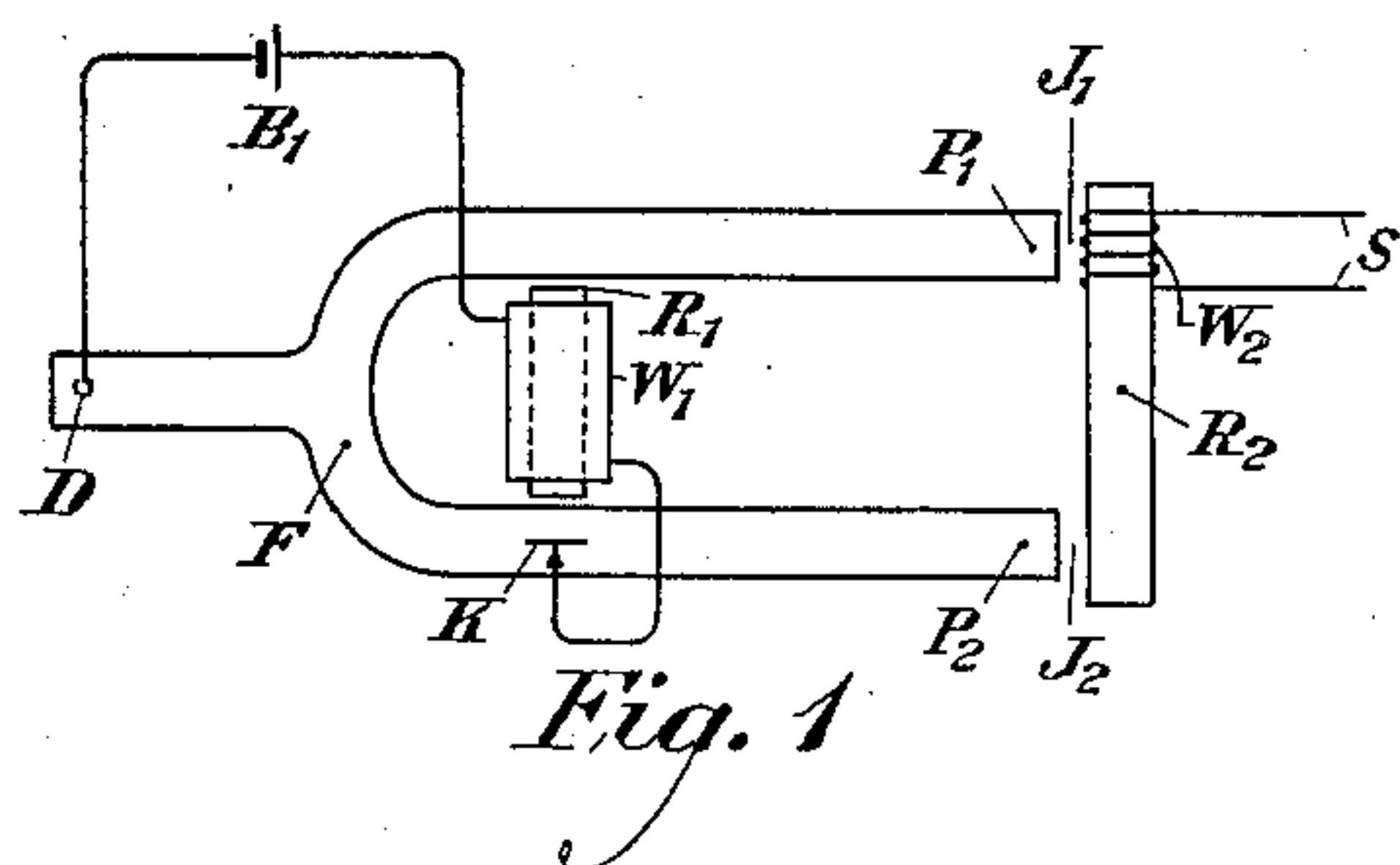


Fig. 1

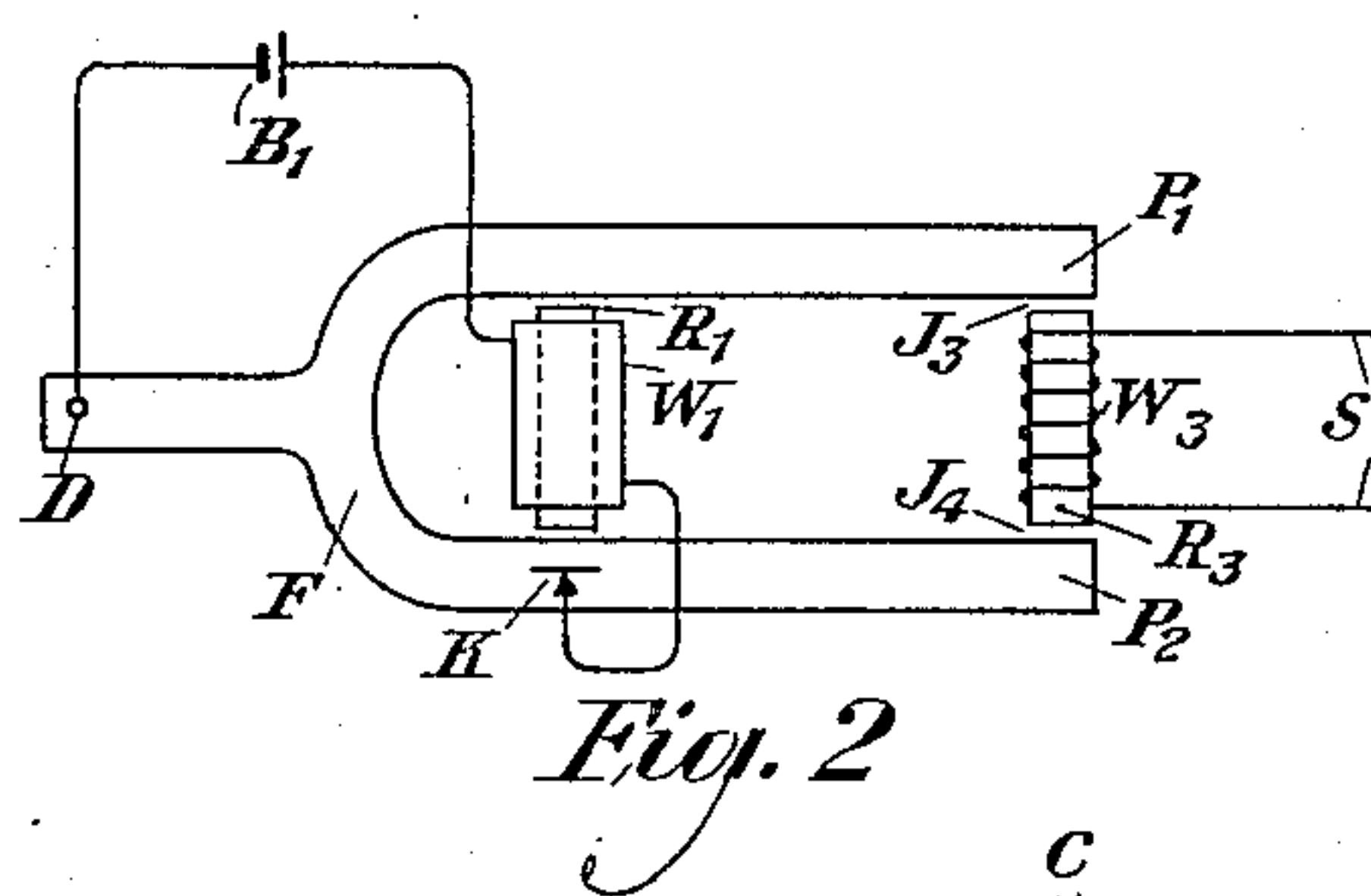


Fig. 2

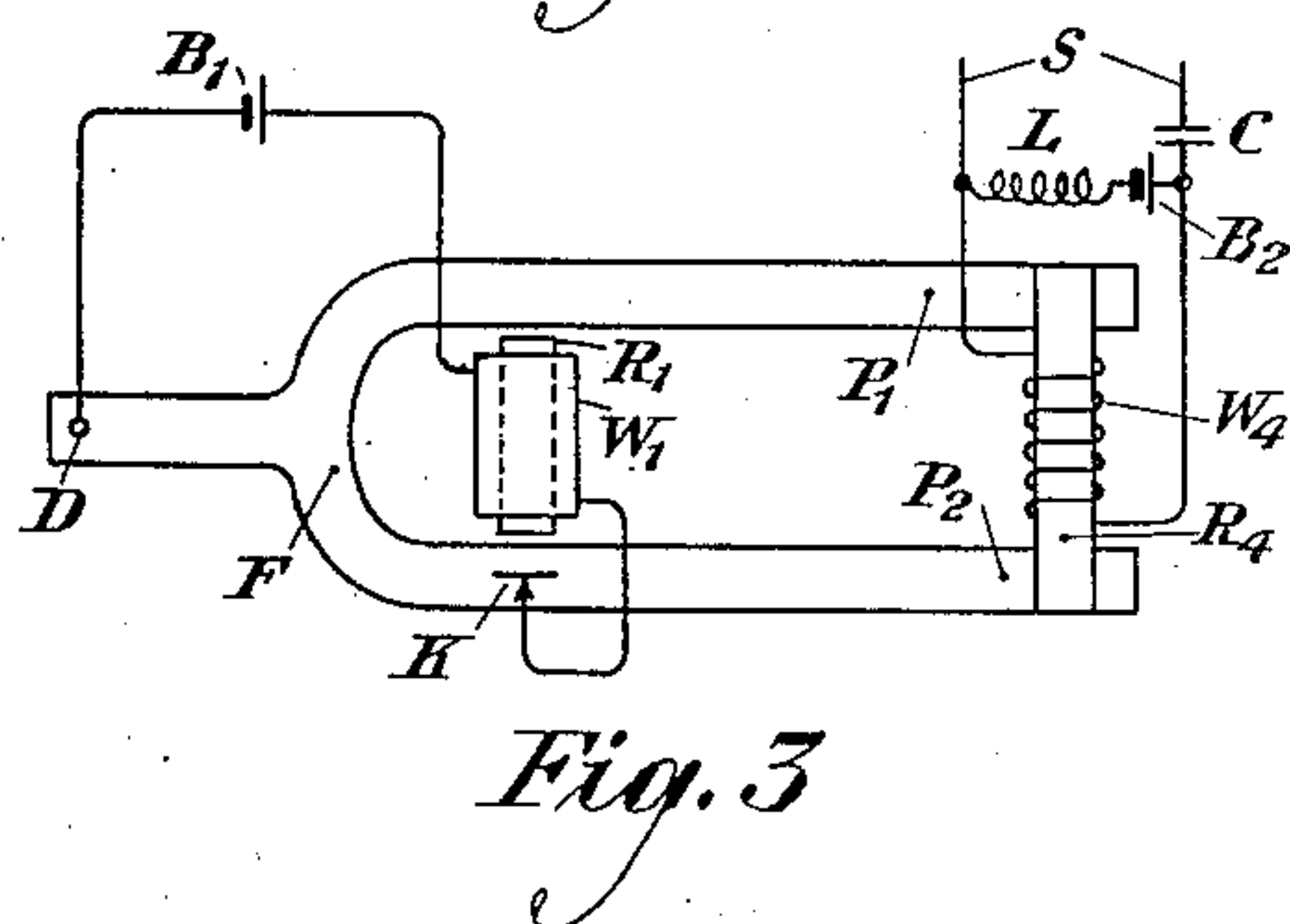


Fig. 3

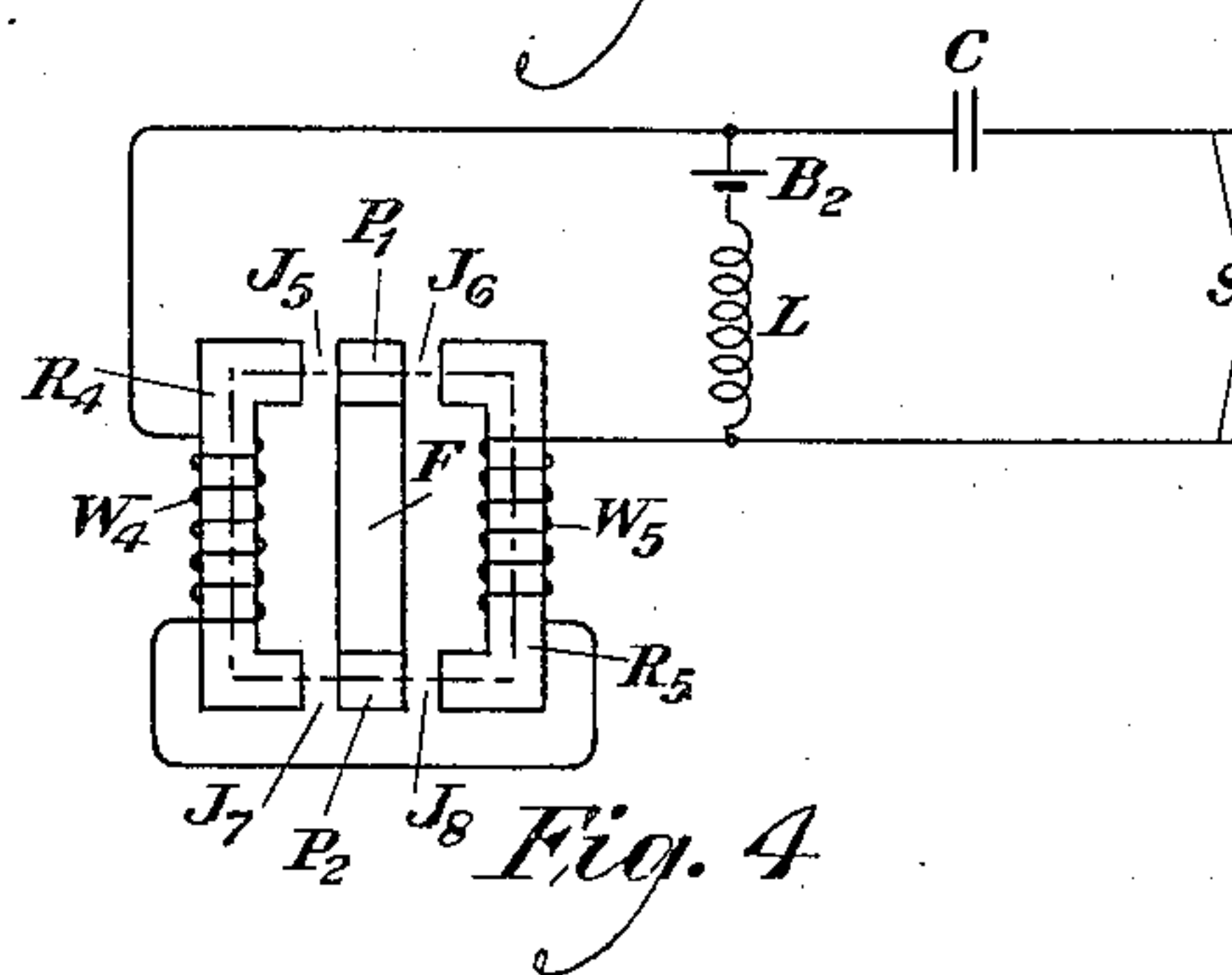


Fig. 4

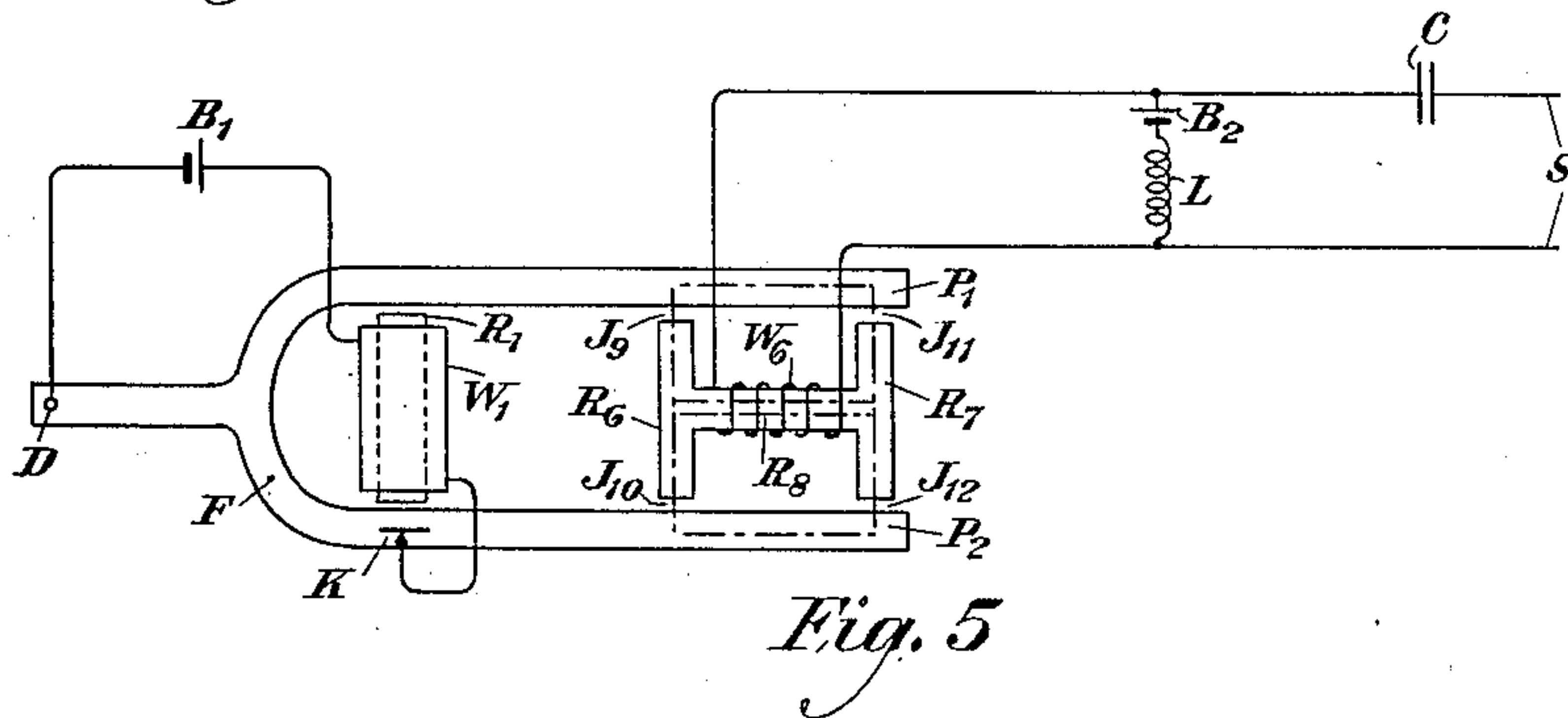


Fig. 5

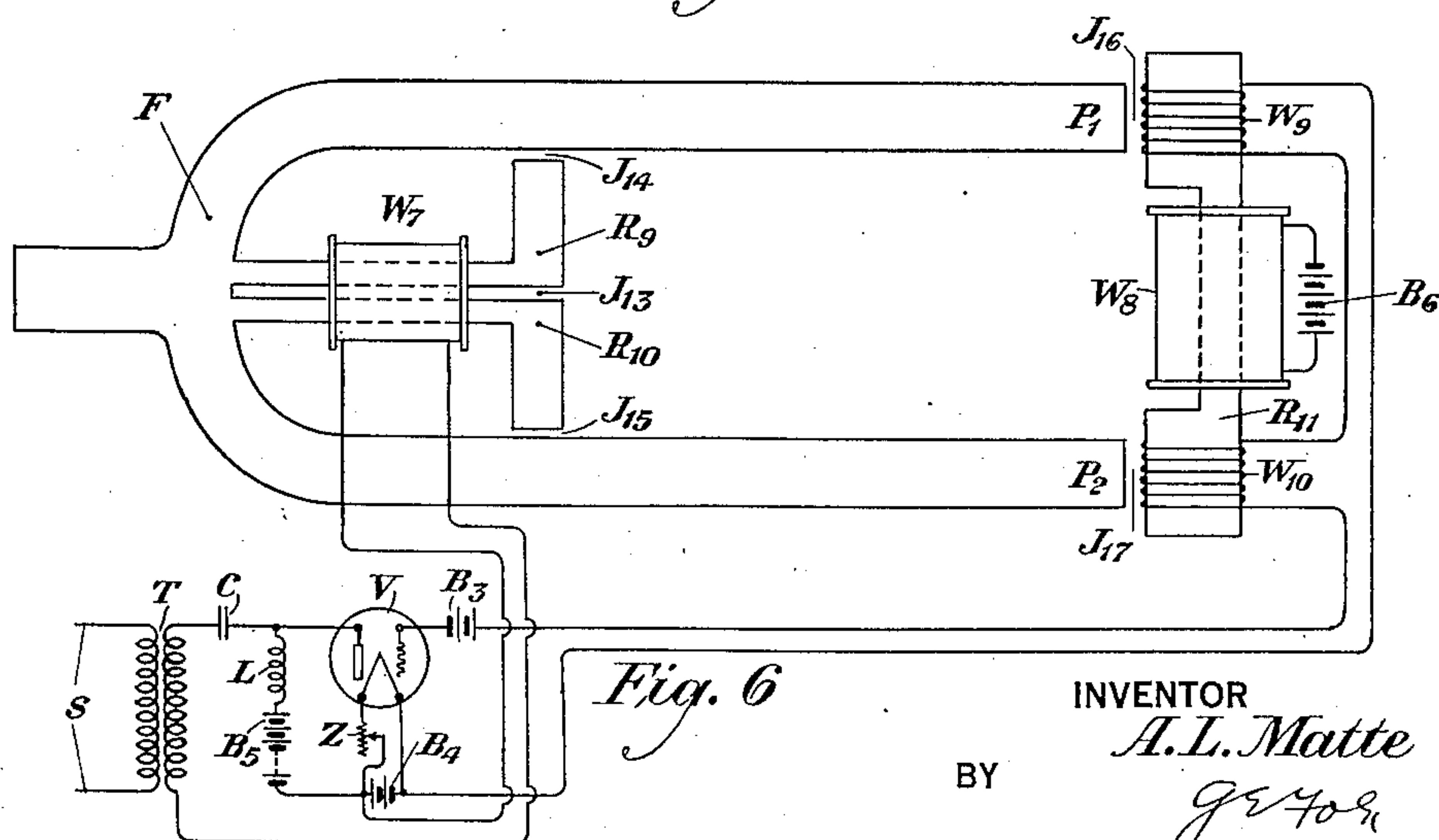


Fig. 6

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TUNING FORK GENERATOR

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This invention relates to tuning forks and tuning fork generators, and more particularly to arrangements for producing current of the frequency of vibration of a tuning fork or of some harmonic of its frequency of vibration.

In general, the vibration of a tuning fork may be made to generate an alternating current in two distinct ways. First, the vibration of the tuning fork may be made to change the reluctance of a magnetic path or circuit to thereby generate an electromotive force in a coil overwound on some portion of this magnetic path or circuit. Second, the flux of a magnetic path or circuit may remain virtually constant; yet the fork may be made to vibrate so that the change in the position of its tines or prongs may divert some of the flux from a number of turns of the coil in which an electromotive force is to be generated. The difference between these two methods will be readily apparent if one recalls that the electromotive force generated when a coil is threaded by a magnetic field is dependent upon the rate of change of the linkages formed by the turns of the coil and the enclosed lines of magnetic induction. Thus, an electromotive force may be produced either by changing the amount of flux enclosed by a given number of turns of wire or by changing the number of turns of wire enclosing a given number of lines of magnetic induction. The principles underlying the two methods enumerated hereinabove will be employed in connection with the invention to be subsequently described.

One of the primary objects of this invention is to generate an alternating current by the continuous action of a tuning fork, the tuning fork being electrically driven.

Another object of this invention is to prevent the electrical driving means of the tuning fork generating arrangement from affecting or interfering with the generating action.

Still another object of this invention is to generate alternating electromotive forces by means of a tuning fork arrangement with which a generating coil is associated by changing the number of effective turns of the generating coil without substantially affecting

the density of the flux threading the generating coil.

While this invention will be pointed out with particularity in the appended claims, the invention itself, both as to its further objects and features will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawing, in which Figure 1 shows how the number of effective turns of a coil of wire may be periodically changed; Fig. 2 shows how the flux threading a coil of wire may be periodically changed; Figs. 3 and 4 show how to produce an alternating current from a tuning fork energized from a local source, so arranged that the driving flux may have substantially no effect upon the circuit in which the current is generated; Fig. 5 shows another embodiment of an electrically driven tuning fork generator for rendering the effect of the driving flux substantially negligible in the circuit producing the generated current; and Fig. 6 represents another arrangement of an electrical driven tuning fork generator regeneratively connected to a vacuum tube system.

Referring to Fig. 1 of the drawing, there is shown a tuning fork F having two tines or prongs P_1 and P_2 . The tuning fork may be mounted very solidly on a rigid, heavy base which is supported on a soft, diffused bed such as may be provided by pads of rubber. This fork may be made, preferably, of ordinary soft steel although it will be clear that it may be made of any well known magnetic alloy which is easily maintained in mechanical vibration.

A coil of wire W_1 wound on a core of iron R_1 is placed between the tines or prongs P_1 and P_2 a considerable distance away from the free ends of these tines or prongs. The current that may flow through the winding W_1 is supplied by a local source of direct current such as is designated as B_1 . One terminal of the source B_1 is connected to a contact D, while the other terminal of this source is connected to the winding W_1 . When contact K is closed, current will flow from the source B_1 through the winding W_1 and over the

curved portion of the tuning fork F between contact K and the fixed contact D.

The tuning fork F may be started by pulling the prongs P_1 and P_2 together, i. e., inwardly. After being started, it is driven continuously, the energy for its continuous operation being supplied from the source B_1 . The contact K provides a make-and-break circuit which periodically interrupts the direct current flowing from the source B_1 . Thus, after the prongs P_1 and P_2 have been drawn together, the contact K will be opened so that no current may flow from the source B_1 through the winding W_1 . As these prongs become released, soon the contact K will become closed and current will then flow from the source B_1 through winding W_1 . Accordingly, that winding will become excited and its core will become threaded with a dense magnetic field. The prongs P_1 and P_2 will then be attracted, thereby opening the circuit including the source B_1 and the winding W_1 at the contact K. Later, contact K will be closed and another pulse of current will surge through the winding W_1 and the prongs P_1 and P_2 will be attracted, i. e., drawn inwardly again. And, so it continues.

Another core of magnetic material is placed adjacent to the free ends of the prongs P_1 and P_2 , this core being so spaced from the free ends of these prongs that gaps J_1 and J_2 , respectively, are established. A coil of wire W_2 is wound about a portion of the core R_2 adjacent to one of the prongs such as P_1 . Coil W_2 has a plurality of turns of wire so spaced that the length of the coil in the direction of its axis is about equal to, and no greater than, the corresponding dimension of the adjacent prong P_1 . The winding W_2 is connected to an output circuit S.

As the tuning fork F vibrates, a magnetic field is intermittently established by winding W_1 , as has been explained hereinabove. A portion of its magnetic flux will flow through the rounded portion of the fork F (which is at the left of the winding W_1). Another portion of this magnetic field will flow over the prongs P_1 and P_2 and over the iron bar or core R_2 . As the fork F vibrates, the magnetic field passing through the bar R_2 will intermittently cut more or less of the turns of wire of coil W_2 . In other words, as the fork vibrates, the number of effective turns of the winding W_2 will be continuously changed and, consequently, an electromotive force of varying magnitude will be established across its terminals. Consequently, an alternating current may flow through the circuit S, the frequency of which will have a component equal to the frequency of vibration of the fork F. An alternating current is thus produced by virtue of the continuous change in the number of effective turns of the coil of wire W_2 even though the flux through the core R_2 were to remain constant.

In the usual arrangement for generating an electromotive force by a tuning fork, the flux threading a coil of wire is varied while all of its turns remain in the path of the threading flux. This is illustrated in Fig. 2. In this arrangement, a core of iron R_3 is placed between the prongs P_1 and P_2 of the fork F so that gaps J_3 and J_4 are respectively established between prongs P_1 and P_2 and the ends of the core R_3 . The driving circuit for it is started is the same as has been described in connection with the arrangement of Fig. 1, similar reference characters designating similar parts.

As the fork vibrates, the size of the gaps J_3 and J_4 are intermittently changed so that the reluctance of the magnetic circuit, which is threaded by the flux produced by winding W_1 and which passes through the prongs P_1 and P_2 , is similarly changed. When prongs P_1 and P_2 are at their extreme outer positions, i. e., when prongs P_1 and P_2 are the greatest distance apart, the reluctance of the magnetic path is a maximum. On the other hand, when these prongs are at their extreme inner positions, i. e., when these prongs are at their least distance apart, the reluctance of the magnetic path is a minimum. Since the winding W_2 is in the path of a periodically varying magnetic flux, the voltage across the terminals of winding W_2 will also vary periodically, this voltage changing from a maximum positive value to a maximum negative value. Accordingly, an alternating current may flow through the circuit S which is connected to the winding W_2 . In this arrangement, it will be apparent that while the effective number of turns of the coil W_2 remains constant, an alternating current may be produced by virtue of the periodical change of the reluctance of the magnetic circuit threading the winding or coil W_2 .

In the arrangements of Figs. 1 and 2 it will be evident that the wave shape of the electromotive forces produced in windings W_2 and W_3 , respectively, are conditioned not only upon the vibration of the fork, but to an equal extent upon the variations of the driving current in winding W_1 . Figs. 3 and 4 represent a top view and an end view, respectively, of an electrically driven tuning fork arrangement for producing an alternating current by virtue of the vibration of the associated tuning fork. In this arrangement, the flux produced by the electrical driving apparatus is divided and split up into two substantially equal parts which are made to oppose and neutralize each other in the generator windings, thereby preventing the fluxes produced by the winding W_1 of the electrical driving apparatus from affecting the current generating action, as will be apparent from the following description. This

represents one of the important features of this invention.

The circuit arrangement for maintaining the tuning fork in continuous vibration after it is started, is shown in Fig. 3, in which reference characters similar to those of Fig. 1 have been employed to designate similar parts. The arrangement disclosed by Figs. 3 and 4 is designed to minimize the effect that the flux established by winding W_1 may have upon the nature of the current generated by the system and flowing through the output circuit S , as suggested hereinabove. Here, two similar yokes of magnetic material R_4 and R_5 are placed adjacent to the prongs P_1 and P_2 of the fork F . The yokes R_4 and R_5 are so placed with respect to the prongs P_1 and P_2 that gaps J_5 and J_6 are established between these yokes and prongs P_1 , and gaps J_7 and J_8 are similarly established between these yokes and prong P_2 . The free ends of the prongs P_1 and P_2 will periodically alter the cross-section and mean length of the effective magnetic path designated in Fig. 4 by the dot-and-dash line, thereby periodically changing the reluctance of this magnetic path.

Coils W_4 and W_5 are wound, respectively, on yokes R_4 and R_5 and are connected in series relationship. A battery B_2 , connected in series relationship with a choke coil L , supplies current to the windings W_4 and W_5 for their energization, the choke coil L being interposed so as to prevent any alternating current generated by the system from becoming shunted through the battery B_2 . A condenser C , preferably of large capacity, is connected in series with the output circuit S in order that none of the direct current from battery B_2 may reach output circuit S , this condenser, nevertheless, permitting the alternating current generated in windings W_4 and W_5 to readily flow therethrough.

As the fork F vibrates, the reluctance of the magnetic path, including yokes R_4 and R_5 and gaps J_5 , J_6 , J_7 and J_8 becomes periodically changed, as has been stated hereinabove. Accordingly, electromotive forces are generated in windings W_4 and W_5 . Since these windings are series aiding, the electromotive forces generated thereby will be additive in effect and will result in the transmission of a current of corresponding frequency through condenser C to the output circuit S . None of this current can be shunted through the circuit of battery B_2 by virtue of the presence of the choke coil L .

The magnetic circuit established by the driving apparatus, i. e., that magnetic circuit produced by winding W_1 shown in Fig. 3, will be substantially without effect upon the voltages generated by windings W_4 and W_5 and therefore without effect upon the wave shape of the corresponding current transmitted through the output circuit S .

The magnetic field established by winding W_1 which flows through the prongs P_1 and P_2 also divides between the yokes R_4 and R_5 . Since the gaps J_5 and J_6 are respectively equal in size to gaps J_7 and J_8 , the magnetic field established by winding W_1 will pass through these yokes in equal amounts. In other words, the flux densities in the yokes R_4 and R_5 due to the magnetic field established by winding W_1 are substantially equal and the directions of the fluxes through yokes R_4 and R_5 are in mutually opposite directions. Accordingly, these fluxes will tend to produce mutually neutralizing electromotive forces and thence be substantially without effect upon the generation of the electromotive forces impressed upon circuit S .

Fig. 5 shows another electrically driven tuning fork arrangement for deriving alternating current from the associated continuously vibrating tuning fork, this arrangement involving a Wheatstone bridge of a magnetic type. Here the core or cores associated with the generating coil are arranged so as to effectively form a magnetic Wheatstone bridge, the generating coil being placed in one of the diagonals of the bridge and the electrical driving apparatus in the other diagonal. Accordingly, the flux produced by the electrical driving apparatus is prevented from interfering with the action of the generating coil and this represents another important feature of this invention.

The magnetic apparatus placed between the prongs P_1 and P_2 of fork F is in the form of a flattened spool, the bases of which are formed by bars R_6 and R_7 and the connecting crosspiece of which is a bar R_8 , all of these bars being made of magnetic material. The cross-piece R_8 is shown midway between bars R_6 and R_7 . Gaps J_9 and J_{10} bridge the spaces between prongs P_1 and P_2 , respectively, and bar R_6 , and gaps J_{11} and J_{12} bridge the spaces between these prongs, respectively, and bar R_7 . A winding W_6 is wound upon the connecting bar R_8 , this winding being supplied with energizing current from a battery B_2 which is connected in series relationship with choke coil L . Choke coil L prevents generated alternating currents from passing through battery B_2 , while condenser C prevents the current from battery B_2 from flowing through the output circuit S . The apparatus employed herein for maintaining the tuning fork in continuous vibration after it is started is the same as has been employed in connection with the arrangement of Fig. 1, the same parts being designated by the same reference characters.

A portion of the magnetic flux derived from winding W_1 flows through bar R_6 and another portion of this flux flows through bar R_7 . Assuming that gaps J_9 and J_{10} adjacent to bar R_6 are substantially equal and that gaps J_{11} and J_{12} adjacent to bar R_7 are

also substantially equal, then more flux may, perhaps, thread bar R_8 than R_7 . But since bar R_8 is interposed midway between bars R_6 and R_7 , the ends of bar R_8 will be at substantially equal magnetic potentials so that substantially no flux may flow therethrough. Accordingly, none of the flux derived from winding W_1 will thread bar R_8 and, consequently, no electromotive forces will be established by the terminals of winding W_8 by virtue of the flux from winding W_1 . In other words, the action of the winding W_8 in the production of electromotive forces will be substantially unaffected by the driving mechanism and circuit.

It will be understood that while the terminals of bar R_8 are shown in a position midway between the terminals of bars R_6 and R_7 , respectively, bar R_8 need not be so placed, for it may be placed in any position with respect to bars R_6 and R_7 so that its terminals are at substantially equal magnetic potentials.

As the prongs P_1 and P_2 of the fork F vibrate, gaps J_9 and J_{10} as well as gaps J_{11} and J_{12} will be periodically changed in length so that the reluctance of the magnetic path followed by the flux arising from the flow of current from battery B_2 through choke coil L and through winding W_8 will be similarly changed. Accordingly, periodical electromotive forces will be generated by winding W_8 and these periodical electromotive forces will result in an alternating current of corresponding frequency which will become transmitted through condenser C and the output circuit S .

Fig. 6 shows a regenerative embodiment of an electrically driven tuning fork arrangement for producing alternating current in the manner described hereinabove in connection with Fig. 1. Here the flux produced by the electrical driving apparatus is prevented from threading the core upon which the generating coil is placed and the flux, whose variations are depended upon to produce the desired electromotive force, is provided by a local source B_6 .

This embodiment includes a vacuum tube system in addition to a tuning fork arrangement. The vacuum tube system includes a three-element vacuum tube V , the grid electrode of which is maintained at a suitable negative potential with respect to the cathode by means of the battery B_3 . The cathode is heated to an electron-emitting temperature by the flow of current therethrough from a battery B_4 , a rheostat Z being interposed in series therebetween so that the current from battery B_4 may be properly regulated. The movable terminal of the rheostat Z is connected to the anode of the vacuum tube V through a battery B_5 and a choke coil L , battery B_5 maintaining the proper operating potential for the anode of the vacuum tube. Part of the output energy of the vacuum tube system

is transmitted through a transformer T , the secondary winding of which is connected to the output circuit S , while the rest of the output energy drives the fork by means of the coil W_7 . Condenser C connected in series with the primary winding of transformer T acts to prevent any of the current from battery B_5 from flowing through the primary winding of transformer T . The tuning fork F includes a pair of L-shaped cores R_9 and R_{10} , between which there is a small airgap J_{13} . These cores also are spaced from the prongs P_1 and P_2 by substantially equal gaps J_{14} and J_{15} , respectively. Coil W_7 is wound about both cores, the terminals of coil W_7 leading to the movable arm of rheostat Z and lower terminal of the primary winding of transformer T , respectively.

An iron core or yoke R_{11} is U-shaped, so designed and so placed with respect to the free ends of prongs P_1 and P_2 that large surfaces become adjacent to prongs P_1 and P_2 , these surfaces being spaced from the free ends of these prongs by gaps J_{16} and J_{17} , respectively. A coil of wire W_8 is wound about the middle section of yoke R_{11} , current for energizing this coil being derived from a battery B_6 . Two coils W_9 and W_{10} are also wound about the outer sections of yoke R_{11} and are connected in series relationship between the positive terminal of battery B_3 and the cathode of vacuum tube V . Each of the coils W_9 and W_{10} includes a number of turns, the overall width of which approximates the width of the prongs P_1 and P_2 , respectively.

When the fork F is in vibration, the prongs P_1 and P_2 swing to both sides of their normal positions, thereby effectively cutting out a number of turns of each of the coils W_9 and W_{10} . The continuous vibration of the prongs P_1 and P_2 results in the generation of periodic voltages by coils W_9 and W_{10} . These coils are connected in series in such a way that the generated voltages will be additive. Consequently, the negative potential of the grid electrode of vacuum tube V with respect to the cathode will be periodically varied, and therefore an alternating current will be produced and transmitted through the primary winding of transformer T . Some of this alternating current energy will be transmitted to the output circuit S . The rest of this energy will be supplied to the coil W_7 so as to produce periodic fluxes in the cores R_9 and R_{10} , in order to maintain the tuning fork F in continuous vibration.

Equal portions of the fluxes produced by coil W_7 are transmitted through cores R_9 and R_{10} . The flux through the prong P_1 will be equal to the flux through prong P_2 , both being oppositely directed. Accordingly, there will be no effect in yoke R_{11} as a result of the flux generated by winding W_7 .

It will be understood that the faces of the yoke R_{11} which are adjacent to the free ends

of prongs P_1 and P_2 are sufficiently extended so that as the prongs P_1 and P_2 vibrate, there will be substantially no change in the size of the gaps J_{16} and J_{17} . Since these gaps practically determine the reluctance of the magnetic circuit followed by the generator flux produced by the exciting winding W_8 , the voltages generated by coils W_9 and W_{10} are merely dependent upon changes in the number of their turns intercepted by the flux proceeding from prongs P_1 and P_2 , respectively.

It will be understood that while a vacuum tube system has been shown in association with tuning fork F in the arrangement of Fig. 6, the vacuum tube system may be omitted and a driving arrangement of the type shown in connection with Fig. 1 may be substituted therefor to maintain the fork in continuous vibration.

While this invention has been shown in certain particular embodiments merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A tuning fork generator comprising an electrical driving apparatus including a magnetic circuit, and means for dividing the magnetic circuit into equal and oppositely directed portions for preventing said electrical driving circuit from changing the wave shape of the generated current.

2. A tuning fork generator comprising means for producing a driving flux, a plurality of windings for producing a generator flux, and magnetic means to substantially shunt said driving flux from the generator windings and thereby prevent the driving flux from affecting the wave shape of the electromotive force generated by the generator flux.

3. The combination of a tuning fork having a natural vibratory period, means for maintaining the tuning fork continuously in vibration by pulling the prongs together at said natural vibratory period comprising a driving magnet, an electromagnet composed of two coils mounted on a common core of iron, the coils of said electromagnet being equally spaced from both of the free ends of the prongs of the tuning fork, and means to prevent the flux of the driving magnet from substantially affecting the magnetic field linked with the coils of the electromagnet.

4. The combination of a mechanically vibrating tuning fork having a predetermined period of vibration, electromagnetic means for continuously vibrating both prongs of said fork, a stationary coil of wire adjacent to said fork the effective number of turns of which is changed by the vibration of said

fork, means for preventing the flux of the electromagnetic means from substantially affecting the flux linked with the stationary coil of wire adjacent to said fork, and a circuit including the stationary coil of wire through which will be transmitted current of a frequency corresponding to the predetermined period of vibration of said fork.

5. In an electrically-driven tuning fork generator in which the desired electromotive force is generated by periodically diverting a substantially constant flux from some of the turns of one or more coils overwound on a separately excited generator core, means for efficiently using the maximum motion of the fork, said means comprising a generator coil located in a fixed position at the ends of the fork, said generator coil being so placed that the motion of both tines will simultaneously cut in and out some of the turns of the generator coil from effective coupling with the flux.

6. In a regeneratively-driven tuning fork generator, means for producing an electromotive force, said means consisting of an immovable generator coil overwound on a separately excited core which is located adjacent to the ends of the prongs of the tuning fork, and means to periodically divert the generator field from some of the turns of the generator coil.

In testimony whereof, I have signed my name to this specification this 15th day of June 1928.

ANDREW L. MATTE.