Nov. 9, 1943. A. G. BABO ET AL 2,333,760

THERAPY APPARATUS

Filed Sept. 2, 1941

Fig. 1.

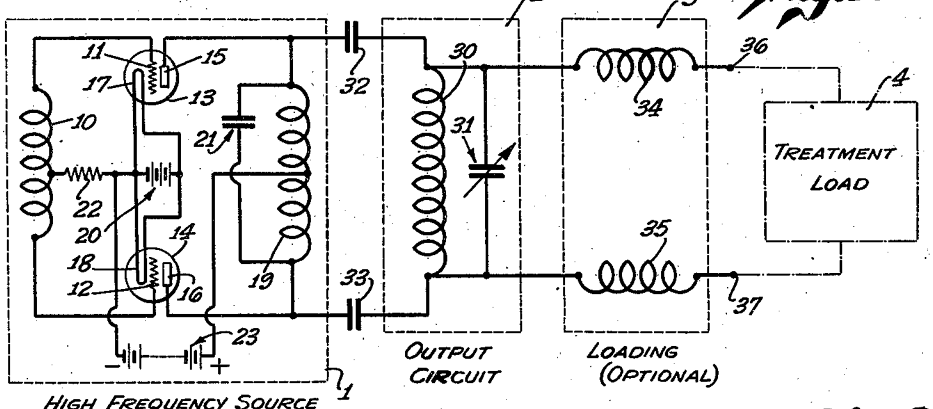



Fig. 2.

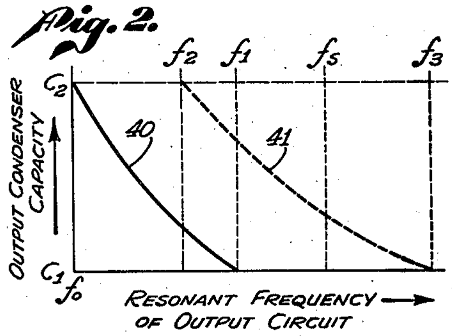



Fig. 3.

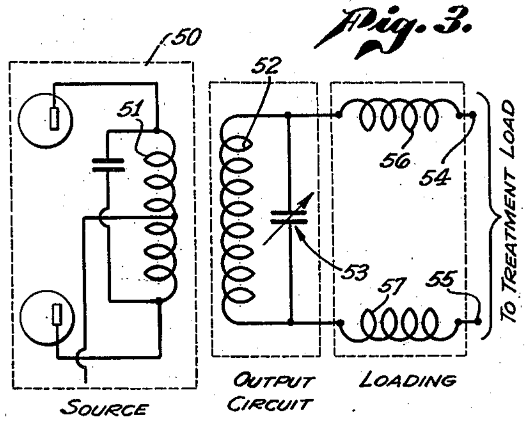
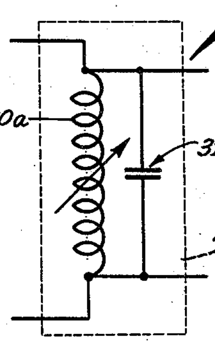



Fig. 6.



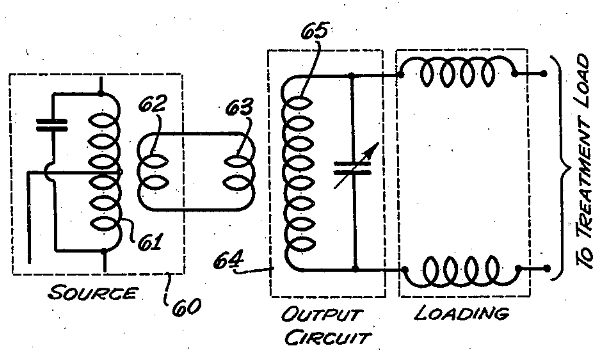




Fig. 4.

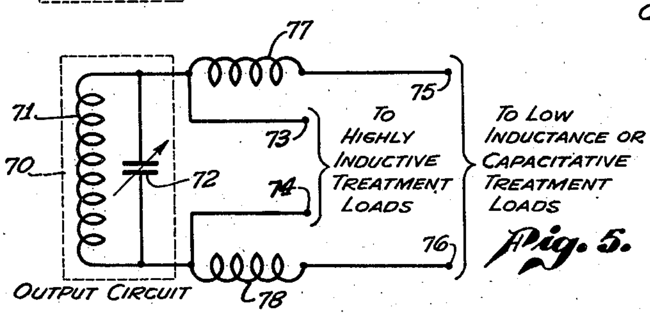



Fig. 5.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Patented Nov. 9, 1943 2,333,760

# UNITED STATES PATENT OFFICE

2,333,760

## THERAPY APPARATUS

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Application September 2, 1941, Serial No. 409,166

10 Claims. (Cl. 128—422)

This invention relates to therapy apparatus and pertains more particularly to an output circuit for a short wave therapy apparatus. This application is a continuation-in-part of our co-pending application, Serial No. 359,030, filed September 30, 1940.

Short wave therapy devices usually consist of a high frequency source, comprising a vacuum tube oscillator, and an output circuit which is adapted to connect the source with the therapy load. The load is usually produced by treatment devices such as a pair of insulated electrodes of extended area which are applied to a patient at spaced positions to subject a portion of the patient to a high frequency electrostatic field, or it may comprise a cable which is wound about the patient to subject a portion of the patient to the combined action of the electromagnetic and electrostatic fields. As another example, a surgical electrode may be connected to the output circuit for the purpose of cutting or coagulating tissues. The impedance of the various loads will differ considerably and for that reason it is preferable to employ a parallel tuned output circuit since such a circuit is capable of considerable impedance variation and it is possible to obtain the desired impedance match between the output circuit and the load.

Parallel tuned circuits at resonance are productive of extremely high voltages when unloaded and require elaborate insulation. In fact, at extremely high frequencies the cost of insulation makes the use of such circuits commercially impractical unless elaborate precautions are taken to prevent their being tuned to resonance when unloaded. Furthermore, the power source is usually set in operation before the load is connected to the apparatus.

It is well known that the magnitude of these no-load voltages at resonance can be decreased by increasing the ratio of the capacity to the inductance in the parallel tuned coupling circuit. This has the disadvantage that the efficiency of the coupling circuit is low. For efficient operation this ratio should be low. However, even for moderately low ratios the voltages developed at no load are too high for practical purposes.

With our circuit it is possible to use a low capacity to inductance ratio or a so-called "low C" circuit without producing high voltages at no load. We are also able to use an inductance having a ratio of reactance to resistance which is very high, that is, an inductance with a high Q. These are important conditions to fulfill since they result in an efficient output circuit. At the same time an output circuit so constructed can be operated with a minimum reaction on the source, wherefore the source can be operated with a minimum deviation from a given frequency. Further, such an output circuit may be satisfactorily used with a very stable source, such as a crystal controlled oscillator. This is of considerable importance at the present time in view of a growing tendency toward Federal restriction of therapy devices to a narrow band of frequencies.

It is a primary object of this invention to produce an output circuit which has a low capacity to inductance ratio and which does not produce inordinately high voltages when unloaded.

Another object of the invention is to provide an output circuit which is incapable of being tuned to resonance when unloaded and which may be tuned to resonance when loaded for a wide variety of loadings.

A further object of the invention is to provide an output circuit which is incapable of being tuned to a frequency as high as the frequency of the source when unloaded, and which is tunable to the frequency of the source when loaded with a predominantly inductive load such as imposed by a normal short wave therapy load.

A further object of the invention is to provide an efficient output circuit which has little reaction on the radio frequency source, wherefore the source operates substantially at constant frequency.

Our invention comprises a parallel resonant output circuit suitably coupled to a source of high radio frequency current for connecting the source to a therapy load such as condenser type electrodes, treatment cables or surgical electrodes. The parallel resonant output circuit comprises an inductance in parallel with a condenser. Either the condenser or inductance may be variable. The output circuit is further provided with output terminals connected to the ends of the inductance and adapted for connection to a treatment device, whereby the treatment load along with any other load produced thereby is connected in parallel with the inductance. The constants of the output circuit are such that it is impossible by varying the capacity of the condenser or the value of the inductance to tune the output circuit to the frequency of the source when no treatment load is connected between the terminals. The constants of the output circuit are further such that the presence of a normal therapy load between the terminals results in a load which is inductively reactive at the frequency of the source in parallel with the inductance. This lowers the total inductive reactance of the coupling circuit and makes it possible to tune the coupling circuit to the frequency of the source by varying the capacity of the condenser or the value of the inductance. The output circuit may comprise loading coils or inductances connected between the terminals and the first-mentioned inductance in order to introduce the desired inductive reactance in parallel with the first-mentioned inductance when the treatment load is connected, if the treatment load does not introduce sufficient inductive reactance.

Further objects and advantages of our invention are either specifically brought out in the ensuing description or will be apparent therefrom.

We have illustrated our invention in the accompanying drawing and referring thereto:

Fig. 1 is a schematic diagram of a short wave therapy circuit embodying our invention;

Fig. 2 is a graph illustrating the operation of our apparatus;

Figs. 3 and 4 are schematic diagrams illustrating alternative modes of coupling the output circuit to the source;

Fig. 5 is a schematic diagram of an output circuit provided with a simple impedance matching network which may be used on extremely high frequencies, for example; and

Fig. 6 is a schematic diagram of an output circuit utilizing a fixed capacity and variable inductance.

Referring to Fig. 1 of the drawing, we have illustrated our invention in connection with a typical high frequency source or generating circuit such as a push-pull oscillator 1 which is surrounded by a dotted rectangle on the wiring diagram. This oscillator may be adapted to produce high frequency current at a wave-length of about 11.5 meters, for example. The source 1 is suitably coupled to an output circuit according to this invention which is enclosed by the dotted rectangle 2.

The high frequency source 1 does not form part of this invention, since substantially any well-known high frequency source may be used, and will be described only briefly. The source is shown as comprising a grid coil 10 having its opposite ends connected respectively to grids 11 and 12 of vacuum tubes 13 and 14 which are also provided with plates 15 and 16 and filaments 17 and 18 respectively. The plates are respectively connected to the opposite ends of a tank coil 19 and the filaments are shown suitably connected to a filament supply device 20. The source is further provided with a tank condenser 21 connected across the tank coil 19 and a grid bias resistor 22 connecting the filaments 17 and 18 to the midpoint of the grid coil 10. A suitable plate voltage supply means 23 is shown connected between the filament side of the grid resistor 22 and the midpoint of the tank coil 19.

The output circuit 2 of this invention is shown as comprising an output inductance 30 and a variable capacity condenser 31 connected in parallel with the output inductance 30. The inductance 30 and the condenser 31 comprise a parallel tuned circuit. The output circuit 2 is shown coupled to the high frequency source 1 through the agency of coupling condensers 32 and 33 which connect the respective ends of the tank coil 19 to the ends of the output inductance 30.

Referring now to Figs. 1 and 2, and more particularly to Fig. 2, a curve 40 is shown which illustrates the relation between the capacity of the output condenser 31 and the resonant frequency of the output circuit when the output circuit is unloaded. The output condenser 31 is variable over a range between a minimum capacity value $C_1$ and a maximum capacity value $C_2$, and the output circuit may thus be tuned to resonance at any frequency lying between a high frequency $f_1$ and a low frequency $f_0$. The inductance of the coil 30 and the capacity of the condenser 31 are so chosen that the frequency $f_1$ lies below the frequency of the source indicated at $f_s$. For that reason it is impossible to tune the output circuit to resonance when it is unloaded. Thus no dangerously high voltages exist in the output circuit at such a time and it is also possible to connect the load to the output circuit without the production of dangerous arcs. Furthermore, the ratio of the capacity of the condenser 31 to the inductance of the coil 30 may be made very low, with resulting high efficiency of the output circuit. By using a high value of inductance it is possible to match higher impedance loads. Furthermore, the inductance 30 may have a high Q.

Our circuit further comprises a loading portion 3 which includes loading coils 34 and 35 the respective ends of which are connected to the respective opposite sides of the inductance 30 and to output terminals 36 and 37. The coils 34 and 35 are inductively reactive at the frequency of the source.

A treatment load 4 is shown connected between the terminals 36 and 37 and is indicated in dot-dash lines. The treatment load 4 produces a current flow in the loading coils 34 and 35 and may either be predominantly capacitatively or predominantly inductively reactive. The treatment load is produced by the current flow through the connections to the treatment devices (which may comprise cables, pads, surgical appliances or other electrotherapeutical or electrosurgical appliances) and the load produced by the current flow through the patient. Various examples of such loads are illustrated in U. S. Patent No. 1,945,867, issued February 6, 1934, to P. C. Rawls.

Until the treatment load is effective, that is until it actually imposes a load on the circuit there is no effective current flow through the coils 34 and 35 and they produce no loading. Hence, they have no appreciable effect on the circuit, since they do not constitute a load. In this unloaded condition, therefore, the output circuit operates according to curve 40.

The values of the loading coils 34 and 35 are so chosen that a normal treatment load will impose an inductively reactive load on the output circuit. This reactance is in parallel with the inductance 30 and effectively lowers the reactance in parallel with the condenser 31 in the output circuit. The value of the inductance 30 is such that when a normal treatment load is connected between terminals 36 and 37, the output circuit may be turned to the frequency of the source by adjusting the condenser to a value within its capacity range.

Dotted curve 41 in Fig. 2 illustrates the relation between the capacity of the output condenser 31 and the resonant frequency of the output circuit when the treatment load is connected between the output terminals for a value of treatment load lying within the normal range. From an inspection of curve 41 it will be seen that the output circuit is tunable between a frequency $f_2$ and a frequency $f_3$ which lie respectively below and above the frequency of the source $f_s$. Furthermore, the output circuit may be tuned to resonance at source frequency $f_s$.

It should be obvious that the output circuit may be coupled to the source in any one of a number of ways and that it is not necessary to use capacity coupling such as illustrated in Fig. 1. For example, the output circuit may be inductively coupled to the source. Referring to Fig. 3, a suitable high frequency source is indicated at 50, for example a source such as illustrated at 1 in Fig. 1. This source is shown as comprising a tank inductance 51 which is inductively coupled to an output inductance 52 which is shunted by a variable output condenser 53. Output terminals 54 and 55 are shown connected to the opposite ends of the inductance 52. Except for the type of coupling, this circuit may be the same as shown in Fig. 1.

In Fig. 4 an arrangement is shown which employs link coupling. A portion of a source is shown at 60 and comprises a tank coil 61 inductively coupled to a link coupling coil 62 which is connected to a second link coupling coil 63. An output circuit according to our invention is indicated at 64 and comprises an inductance 65 which is inductively coupled to the coil 63. The output circuit may otherwise be the same as illustrated in Fig. 1.

It is to be pointed out that it is not always necessary to employ loading coils to cause the treatment load to impose an inductive load on the output circuit. The load a given treatment device itself imposes on the system will vary with frequency. For example, we have found the circuit illustrated in Fig. 1 quite satisfactory for all normal treatment loads encountered at 11.5 meters. However, at a higher frequency, for example 5.75 meters, the inductive reactance of some normal treatment loads is so high that loading coils are not necessary.

In Fig. 5 an output circuit according to this invention is illustrated at 70 and is shown as comprising an inductance 71 suitably coupled to a source not shown, and a variable capacity 72 in parallel with the inductance 71. The apparatus is shown provided with two sets of output terminals, 73 and 74, and 75 and 76, respectively. The first set is connected directly to the opposite sides of the inductance 71 while the second set is connected to the ends of the coil 71 through loading coils 77 and 78. Thus highly inductive treatment loads are connected between terminals 73 and 74 and capacitative or low inductance loads are connected between terminals 75 and 76.

It is to be understood that where a variable capacity is shown, for example condenser 31, it may include one or more fixed capacities connected in series or parallel with a variable capacity. The total capacity is of course varied by the variable capacity.

It should be apparent that tuning of the output circuit may be effected with a variable inductance element rather than a variable condenser element as in the previous examples. Under such circumstances a fixed condenser element may be employed in the place of the variable one. In Fig. 6 the output circuit 2 of Fig. 1 is indicated at 2*a* as modified for inductive tuning. Thus the fixed inductance 30 has been replaced by a variable inductance 30*a* and the variable condenser 31 has been replaced by a fixed one indicated at 31*a*. The variable inductance 30*a* may be constructed in any of the manners well known in the art. For example, the inductance may be tuned by a slider moving in a helical path along the coil turns as is commonly used in transmitter practice.

With the output circuit 2*a* substituted for the output circuit 2 of Fig. 1, the resonant frequency of the output circuit 2*a* is tunable between a first frequency and a second higher frequency as the inductance of coil 30*a* is varied between its highest and lowest values. The values of inductance and capacity are such that with the treatment load disconnected, said second frequency is lower than the frequency of the source 1. Hence it is impossible by varying the value of the inductance 30*a* to bring the output circuit to resonance with the source 1 when the treatment load 4 is disconnected.

As pointed out previously, connection of the treatment load 4 to the terminals 36 and 37 is reflected in the output circuit as an inductively reactive load either because the treatment load is predominantly inductively reactive or because the combination of the loading device 3 and load 4 is inductively reactive. Thus, connection of the load 4 has the same effect as the placing of an inductance in parallel with the inductance 30*a* and decreases the total inductance in parallel with the condenser 31*a*. As a result, the output circuit is now tunable to a higher frequency than it was before and the constants of the circuit are preferably such that the output circuit is tunable to the frequency of the source 1.

It should be obvious that the variable condensers in the output circuits illustrated in Figs. 3, 4 and 5 may be replaced by fixed ones and the corresponding parallel fixed inductances may be replaced by variable ones. In every case the same advantages as realized with variable condensers will be obtained, that is, it will be impossible to tune the output circuit to the resonance with the high frequency source until the treatment load is connected.

Having now described and illustrated particular forms of our invention, we wish it to be understood that our invention is not limited to the specific forms or arrangements herein described and shown, but rather to the contemplation expressed by our claims.

We claim:

1. A high frequency electrotherapy apparatus provided with a high frequency generating circuit means stabilized at a given frequency level; and an output circuit means coupled to said generating circuit means including an inductance element and having a resonant frequency different from said given frequency level, said output circuit means including a capacity element parallel connected to said inductance element and output terminals adapted to receive, in parallel connection to said inductance and capacity elements, a treatment device adapted to impose a given inductive load upon said output circuit means, one of said elements being variable, the value of said elements, with respect to such inductive load, being such that said output circuit remains out of resonance with said generating circuit means at all values of said one element when said treatment device is unconnected, and being such that said output circuit means can be brought into resonance with said generating circuit means through the agency of said one variable element when said treatment device is connected.

2. A high frequency electrotherapy apparatus comprising: a current source adapted to supply electrical current at a high radio frequency; and an output circuit coupled to said source, said output circuit comprising an inductance element, a capacity element connected in parallel with said inductance element and output terminals connected in parallel with said inductance element, one of said elements being variable over a range between a maximum and a minimum value, the value of the other of said elements being such that said output circuit is resonant to a frequency lower than the frequency of said source when said one element has a minimum value, said output circuit being resonant to the frequency of the source when said one element has a value in said range and a normal treatment load is connected between said terminals.

3. A high frequency electrotherapy apparatus provided with a high frequency generating circuit means stabilized at a given frequency level; and an output circuit means coupled to said generating circuit means including an inductance and having a resonant frequency different from said given frequency level, said output circuit means including a variable capacity parallel connected to said inductance and output terminals adapted to receive, in parallel connection to said inductance and said variable capacity, a treatment device adapted to impose a given inductive load upon said output circuit means, the value of said inductance and such capacity, with respect to such inductive load, being such that said output circuit remains out of resonance with said generating circuit means at all values of said variable capacity when said treatment device is unconnected, and being such that said output circuit means can be brought into resonance with said generating circuit means through the agency of said variable capacity when said treatment device is connected.

4. A high frequency electrotherapy apparatus comprising: a current source adapted to supply electrical current at a high radio frequency; treatment circuit means including a treatment device adapted for application to a patient, said circuit means comprising an inductively reactive load at the frequency of said source when said device is operatively associated with a patient and a negligible load when said device is not operatively associated with a patient; and an output circuit associating said treatment circuit means with said source, said output circuit comprising an inductance in parallel with said treatment circuit means and a variable capacity condenser in parallel with said inductance, the relative values of said inductance and said capacity being such that said output circuit is tunable to resonance when said treatment device is operatively associated with a patient and is not tunable to resonance when said treatment device is not operatively associated with a patient.

5. A high frequency electrotherapy apparatus comprising: a current source adapted to supply electrical current at a high radio frequency; and an output circuit coupled to said source, said output circuit comprising an inductance, a capacity connected in parallel with said inductance and output terminals connected in parallel with said inductance, said capacity being variable over a range between a maximum and a minimum value, the value of said inductance being such that said output circuit is resonant to a frequency lower than the frequency of said source when said capacity is at said minimum value, said output circuit being resonant to the frequency of said source when said capacity has a value within said range and a normal treatment load is connected between said terminals.

6. An apparatus as set forth in claim 5, comprising in addition, loading coils connected between said terminals and said inductance.

7. In an electrotherapy apparatus having a source of high radio frequency current, an output circuit coupled to said source and comprising: an inductance; a capacity connected in parallel with said inductance and being capable of variation over a range between a low value and a high value; and output terminals connected to the opposite sides of said inductance, the value of said inductance being such that said output circuit is resonant to a frequency lower than the frequency of said source when no load is connected between said terminals and said capacity is at said minimum value, said output circuit being resonant to the frequency of said source when a normal treatment load is connected between said terminals and said capacity has a value within said range.

8. An apparatus as set forth in claim 7, said output circuit further including a loading coil connected between each of said terminals and the ends of said inductance.

9. In an electrotherapy apparatus having a source of high radio frequency current, an output circuit coupled to said source and comprising: an inductance; a capacity connected in parallel with said inductance and being capable of variation over a range between a low value and a high value; and output terminals connected to the opposite sides of said inductance, the value of said inductance being such that said output circuit is resonant to a frequency lower than the frequency of said source when no load is connected between said terminals and said capacity is at said minimum value, said output circuit being resonant to the frequency of said source when a normal predominantly inductively reactive treatment load is connected between said terminals and said capacity has a value within said range.

10. A high frequency electrotherapy apparatus provided with a high frequency generating circuit means stabilized at a given frequency level; and an output circuit means coupled to said generating circuit means including a capacity and having a resonant frequency different from said given frequency level, said output circuit means including a variable inductance parallel connected to said capacity and output terminals adapted to receive, in parallel connection to said variable inductance and said capacity, a treatment device adapted to impose a given inductive load upon said output circuit means, the value of said inductance and such capacity, with respect to such inductive load, being such that said output circuit remains out of resonance with said generating circuit means at all values of said variable inductance when said treatment device is unconnected, and being such that said output circuit means can be brought into resonance with said generating circuit means through the agency of said variable inductance when said treatment device is connected.

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