Dec. 23, 1952 E. C. WITSENBURG ET AL 2,623,176

HIGH-FREQUENCY HEATING APPARATUS

Filed Aug. 31, 1949

Fig. 1.

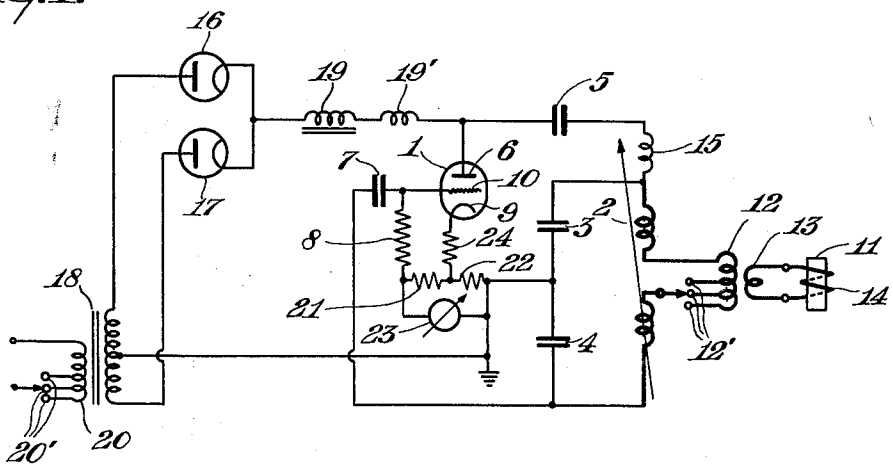
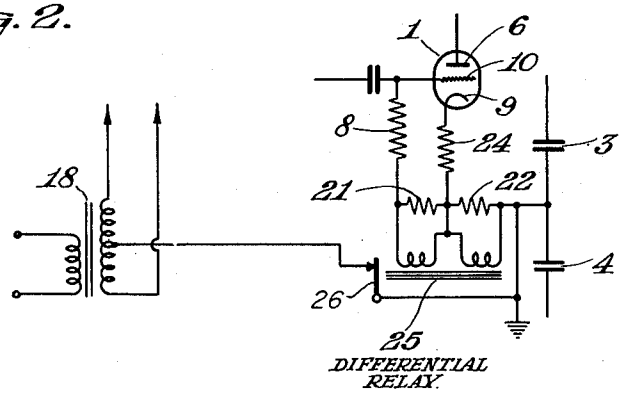


Fig. 2.



INVENTORS
HENDRIK ADOLF TEUNISSEN
EMILIUS CAROLUS WITSENBURG
BY Fred M Vogel
AGENT.

Patented Dec. 23, 1952

2,623,176

UNITED STATES PATENT OFFICE

2,623,176

HIGH-FREQUENCY HEATING APPARATUS

Emilius Carolus Witsenburg and Hendrik Adolf Teunissen, Eindhoven, Netherlands, assignors to Hartford National Bank and Trust Company, Hartford, Conn., as trustee

Application August 31, 1949, Serial No. 113,312
In the Netherlands September 2, 1948

8 Claims. (Cl. 250—36)

1

For the inductive heating of metal articles or for the capacitative heating of articles consisting of non-conducting material, high-frequency heating apparatus is known, in which the high-frequency energy is taken from the output circuit of a regeneratively arranged electron discharge tube.

In order to obtain a satisfactory efficiency it is known to use a class-C electron-tube oscillator, the output circuit of which is included in the anode-circuit and from which a positive feedback voltage is taken. The positive feedback voltage is supplied, by way of a grid condenser, to the control grid which is connected to the cathode by way of a grid-leak resistance.

To obtain optimum efficiency it is necessary to match the load resistance to the oscillator, in other words to ensure that the tube is maximally controlled with respect to voltage and at the same time maximally controlled with respect to current. Both in the case of inductive and capacitative coupling between oscillator and load, the coupling factor between oscillator and load may be variable for matching the load, limited matching being also possible by varying the positive feedback of the tube oscillator.

If the high-frequency heating apparatus is used for heating articles of different kind and size, the power supplied to the load should be adjustable. To this end it is usual to make the supply voltage of the oscillator adjustable.

To indicate the oscillator load, use may be made of a device indicating anode current and grid current since, as is well known, the anode current and grid current increase and decrease respectively with an increase in load.

The present invention has for its object to provide an indication of load matching in high-frequency heating apparatus of the said type, to permit adjustment to optimum load matching and/or to avoid detrimental overloading of the oscillator tube.

According to the invention, this is achieved in a simple manner in high-frequency heating apparatus of the aforesaid type by using as an indicator of load-matching a differential device which is controlled in opposite senses by the anode current and the grid current.

The differential device preferably consists of a pointer device with a central zero position.

If a differential pointer device is chosen such that in a normal, but otherwise arbitrary working condition and optimum load matching, the influences exerted by the anode current and the grid current compensate one another, it is surprisingly found that the indication obtained consistently indicates practically optimum load matching in working conditions varying within wide limits, such as occur upon variation of, say, the oscillator supply voltage, the coupling between oscillator and load, the oscillator back-coupling or a combined variation of these factors. Upon wrong matching the direction of deviation of the pointer device indicates undermatching or overmatching.

2

The pointer device may comprise scales which are calibrated in terms of the power supplied to the load for different oscillator supply voltages.

According to a further feature of the invention, a differential device may also be used, whilst retaining the aforesaid advantages, to indicate or prevent detrimental overloading of the oscillator tube. For this purpose the differential device preferably consists of a differential relay functioning as a maximum relay having a normally closed contact placed in the anode supply circuit.

In order that the invention may be more clearly understood and readily carried into effect, one example will now be described with reference to the accompanying drawing.

Fig. 1 is a schematic diagram of one preferred embodiment in accordance with the invention; and

Fig. 2 is a schematic diagram of a modification of the circuit shown in Fig. 1.

In the circuit arrangement shown in Fig. 1, the high-frequency energy is taken from a class-C connected electron tube oscillator comprising a directly heated triode 1.

In the anode circuit of the electron tube oscillator, consisting of a Colpitt's arrangement, the frequency determining oscillatory circuit comprising a coil 2 and series-connected condensers 3, 4 is connected to the anode 6 of the triode by way of a blocking condenser 5. The positive feedback voltage is taken from the capacitative voltage divider formed by the condensers 3, 4 and is supplied, by way of a grid condenser 7, to the control grid 10 which is connected to the cathode 9 by way of a grid resistance 8.

The circuit current appearing in the oscillatory circuit upon oscillation of the circuit arrangement is used for heating a workpiece 11. For this purpose a part 12 of coil 2 is inductively coupled with a coupling coil 13 which usually consists of a single turn and is connected to a work coil 14.

For optimum load matching, the coil part 12 is furnished with tapping points 12', so that the

turns ratio of the transformer constituted by coil part 12 and coupling coil 13 is adjustable in steps. Furthermore, load matching is obtainable by placing an auxiliary coil 15 in the anode circuit of the oscillator tube, which coil, together with the parts of coil 2 not forming the coupling coil 12, constitute an autotransformer having a variable coupling factor. This may be effected by arranging an axially movable coupling coil 15 concentrically in coil 2.

The supply voltage of the oscillator circuit arrangement is obtained by full wave rectification, by means of rectifiers 16, 17, of an alternating voltage of mains frequency which is taken from the secondary of a transformer 18. This direct voltage is supplied, by way of chokes 19, 19', to the anode 6 of triode 1. The primary 20 of the transformer 18 is provided with tapping points 20', so that the supply voltage is variable, in order that the power to be supplied to the load may be variable.

In order that, with greatly varying working conditions, optimum load matching is consistently possible and/or detrimental overloading of the oscillator tube may be avoided, a differential pointer device is used and is controlled in opposite senses by the anode-current and the grid-current.

This may consist of a differential device comprising two coils connected in the anode-circuit and grid-circuit respectively, but it is preferred to use, as in the present example, a combination of resistances 21 and 22, shunted by a pointer device 23 having a central zero position, and connected in the grid-circuit and anode-circuit respectively. The resistances 21 and 22 are chosen such that in the case of optimum load matching, the pointer of the device 23 is in the central zero position.

In the case of optimum load matching, the indication is consistently practically zero and independent of the working conditions. In the case of wrong matching a deviation to the one side indicates undermatching, whereas a deviation to the other side indicates overmatching also with respect to the value. The indication with respect to load matching is more accurate as the supply voltage increases.

In the circuit arrangement shown, the feedback factor of the oscillator, upon variation of the transformation ratio, varies in such manner as to counteract optimum load matching. This may be prevented by using a current dependent resistance acting as a grid-resistance 8.

Some data for circuit components which have been found satisfactory in practice, for use in the circuit shown in the drawing, are given below:

The electron tube oscillator comprises two parallel-connected Philips transmission triodes type TA 12/20

Maximum power supplied, 20 kilowatts
Maximum anode voltage, 10 kilowatts
Maximum anode current per tube, 1.9 amp.
Maximum grid current per tube, 0.5 amp.
Pointer device: voltmeter with central zero position and a maximum deviation at approximately 5 volts.
Value of the resistance 22 placed in the anode-circuit 1 ohm.
Value of the resistance 21 placed in the grid-circuit: 7 ohms.

The high-frequency furnace used in practice should have a great working security. For this purpose it is known to connect in the cathode-circuit a resistance 24 providing a negative grid-bias by which overloading is counteracted. In order to reduce the possibility of detrimental overloading, however, in the case of abnormal handling of the heating installation, as shown in Fig. 2, a differential relay 25 functioning as a maximum relay may be used as a differential device, which relay comprises a normally closed contact 26 placed in the anode supply circuit.

A device of this type used for preventing overloading permits the use of a smaller cathode resistance or even the omission of this resistance, which results in a higher efficiency of the heating installation.

The invention may also be used in oscillator arrangements other than that shown in the drawing, for example in tube oscillators, in which the feedback voltage is taken from a feedback coil which is placed in the grid-circuit and is inductively coupled with the frequency determining oscillatory circuit included in the anode-circuit, and may also be used in oscillation arrangements with capacitative coupling of the load.

What we claim is:

1. A high-frequency heating apparatus comprising a class C electron tube oscillator, having a variable supply voltage and an output circuit included in the anode circuit, from which output circuit a positive feedback voltage is taken and supplied, by way of a grid condenser, to a control grid connected to the cathode by way of a grid leakage resistance, and furthermore comprising means for load matching, characterised in that a differential device controlled in opposite senses by anode current and grid current is provided for indicating load-matching.

2. A high-frequency heating appaartus as claimed in claim 1, characterised in that the differential device comprises two coils which are connected in the anode-circuit and grid-circuit respectively.

3. A high-frequency heating apparatus as claimed in claim 1 characterised in that both the grid circuit and the anode circuit of the oscillator comprise a resistance, which resistances are shunted by the said differential device.

4. A high-frequency induction heating system comprising a class C oscillator including an electron discharge tube having a cathode, a grid and an anode, a resonant output circuit coupled to said anode, a condenser regeneratively coupling said output circuit to said grid, means to couple said output circuit to a load, and means to supply operating potentials to the electrodes of said tube to sustain oscillations therein whereby an increase in load results in an increase in anode current and a decrease in grid current; and apparatus for indicating optimum matching of said oscillator to said load including means coupled to the grid of said tube to develop a first voltage proportional to said grid current, means coupled to the anode of said tube to develop a second voltage proportional to said anode current, a differential indicator, and means to apply said first and second voltages in opposing senses to said indicator.

5. An arrangement, as set forth in claim 4, wherein said differential indicator comprises first and second coils to which are applied said first and second voltages respectively, and a zero center pointer actuated by said coils and occupying a zero position when the voltages applied thereto are equal.

6. An arrangement, as set forth in claim 5,

wherein said first and second voltages are of equal amplitude in the optimum load matching condition of said oscillator.

7. An arrangement, as set forth in claim 6, wherein said indicator further includes a plurality of calibrated scales corresponding to predetermined supply potentials.

8. A high-frequency induction heating system comprising a class C oscillator provided with an electron discharge tube having a cathode, a grid and an anode, a resonant output circuit coupled to said anode, a condenser regeneratively coupling said output circuit to said grid, means to couple said output circuit to a load, and means to supply operating potentials to the electrodes of said tube to sustain oscillations herein whereby an increase in load results in an increase in anode current and decrease in grid current; and apparatus for indicating matching of said oscillator to said load including means coupled to the grid of said tube to develop a first voltage proportional to said grid current, means coupled to the anode of said tube to develop a second voltage proportional to said anode current and equal to

said first voltage in the optimum matching condition of said oscillator, a differential relay, means to apply said first and second voltages in opposing directions to said relay whereby said relay is actuated when said second voltage exceeds said first voltage, and means responsive to the actuation of said relay to interrupt said supply potentials.

EMILIUS CAROLUS WITSENBURG.
HENDRIK ADOLF TEUNISSEN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,898,432	Edwards	Feb. 21, 1933
2,261,153	Gieringer	Nov. 4, 1941
2,420,857	Brown	May 20, 1947
2,470,443	Mittelmann	May 17, 1949

FOREIGN PATENTS

Number	Country	Date
576,460	Great Britain	Apr. 4, 1946