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MEANS FOR EXAMINING A SUBSTANCE

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Fig.1

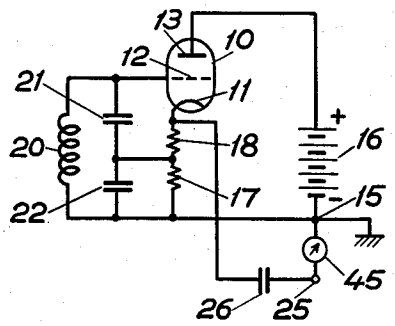
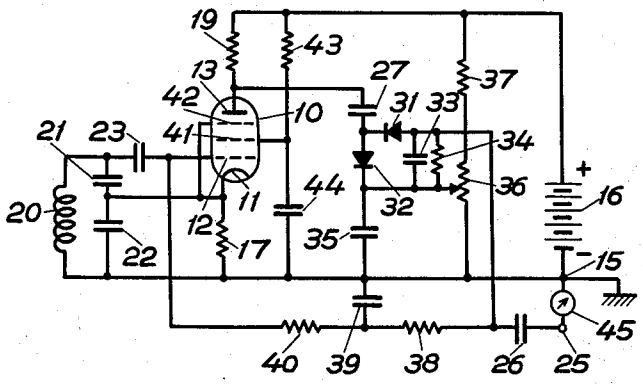


Fig.2



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MEANS FOR EXAMINING A SUBSTANCE

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10 Claims. (Cl. 331—65)

This invention is a continuation-in-part (as to all common subject matter) of the copending application, Serial No. 521,504, filed July 12, 1955, now abandoned, by Mr. Sverre Walter and myself for improvements in metal detector or magnetic bore-hole logger, which application will now be permitted to lapse without prejudice, in view of its being superseded by this present application.

It is know that the change in the magnification factor of a resonant circuit caused by a body moved into a magnetic or electric field from the circuit is dependent on the substance in the body, and it has been proposed to utilize this effect in the construction of metal detectors or bore-hole loggers and equivalent as well as in means for sorting of coal or ore. To be useful in practice a device of this sort must have a very high sensitivity to changes in the magnification factor.

In a known device with high sensitivity, the resonant circuit is a parallel-resonant circuit used as grid circuit in a so-called "Franklin oscillator". The Franklin oscillator consists of two cascaded resistance-coupled vacuum tubes with a feedback connection from the anode of the second tube to the grid of the first tube. The feedback circuit contains a large series resistance which together with the resonance impedance of the parallel-resonant circuit between the grid and the cathode of the first tube constitutes a voltage divider determining the feedback ratio of the oscillator. As the resonance impedance of the circuit is proportional to the magnification factor of the circuit, the feedback ratio is dependent on the magnification factor, and if the oscillator works on a linear part of the tube characteristics and near the critical feedback ratio, the amplitude of oscillation is very sensitive to changes in the magnification factor. Through a measurement of the changes in the amplitude of oscillation it is in this way possible to detect a piece of metal fed into the coil of the resonant circuit, even if the diameter of the piece of metal is less than one thousandth the diameter of the coil.

The known device is, however, very sensitive to changes in the tube characteristics, and the sensitivity mentioned above is attainable only if the oscillator is provided with means for automatic amplitude stabilization, which, however, should be provided with a certain time-delay so that transient changes in the amplitude can develop. The amplitude stabilization has to be very powerful, so that one or more amplifying stages are needed in this circuit in addition to the two tubes in the oscillator.

It is the object of the present invention to provide a means of the kind described which is simpler in design and has higher sensitivity than previously known means.

It is another object of the invention to provide a means of the kind described which has the stability necessary for its use as bore-hole logger without the need for any stabilizing or compensating arrangements.

A further object is to provide an oscillator design for a means of the kind described having excellent stability and sensitivity and still utilizing one single vacuum tube.

A still further object of the invention is to provide an

oscillator design for a means of the kind described in which the single oscillator tube may be relied on even for amplification of the oscillator voltage without any impairment in the sensitivity of the oscillator part caused by loads connected to said amplified voltage. The invention is characterized in that the resonant circuit of the oscillator is a series-resonant circuit and that the feedback ratio of the oscillator is determined by the ratio between the voltage across one reactive element in the resonant circuit and the input voltage to said circuit.

Since the ratio between the voltage across the coil or the capacitor in a series resonant circuit and the input voltage to the circuit at resonance equals the magnification factor of the circuit, the feedback ratio of the oscillator always is proportional to the magnification factor in such an arrangement, and the feedback ratio can be made larger than one. The amplifier constituting part of the oscillator therefore need not have any high voltage gain and may work as a pure power amplifier, the problem of non-linearities and dependency on tube characteristics thus being small. It is especially advantageous to utilize a cathode connected vacuum tube as oscillator together with the resonant circuit.

The invention will best be understood from the description below with reference to the accompanying drawing, in which Figs. 1 and 2 show two preferred forms of the invention. The fundamental design of the oscillator is the same in the two embodiments, but the tube in Fig. 2 is utilized both as oscillator tube and as amplifier tube for the output voltage. The arrangement in Fig. 2 is further provided with a circuit for amplitude stabilization.

In Fig. 1 the numeral 10 designates a tube having a cathode 11, grid 12 and plate 13. The plate 13 is connected to the plus terminal of a battery 16, and the cathode 11 is in series with two cathode resistors 17 and 18 connected to the minus terminal of the battery 16 and to a ground terminal 15. A coil 20 and two series connected capacitors 21 and 22 are connected between the grid 12 of the tube and ground 15, the common terminal of the capacitors 21 and 22 being connected to the junction point of the cathode resistors 17 and 18. An output terminal 25 is via a coupling capacitor 26 connected to the cathode 11 of the tube, and is supposed to be connected to a voltmeter 45 or a sensitive relay for measurement or indication of the amplitude of oscillation, which is a measure on the substance influencing the resonant circuit. The capacitor 22 shunting the cathode resistor 17 is large compared to the capacitor 21, and its reactance is low compared to the resistance in the resistor 17 at the working frequency of the device. The tube 10 together with the battery 16 and the cathode impedance consisting of resistor 18 in series with the parallel connection of resistor 17 and capacitor 22 may be regarded as a cathode-connected amplifier, loaded with a series-resonant circuit consisting of the coil 20 and the capacitor 21. Because of the feedback from the resonant circuit to the grid 12 of the tube the shown arrangement works as an oscillator, in spite of the fact that the voltage gain from the grid 12 to the output over capacitor 22 is less than one. This is so because the necessary voltage gain is provided by the series-resonant circuit.

It is a well-known fact that the ratio between the voltage across the coil in a series-resonant circuit and the input voltage to the circuit equals the magnification factor of the circuit at resonance. A series resonant circuit thus can provide a voltage gain larger than one, in certain cases several hundred times. The voltage of the coil is however in quadrature to the input voltage of the series-resonant circuit, and the purpose of the capacitor 22 in the shown arrangement is to provide the phase displacement of the output voltage from the amplifier necessary to get the correct phase angle in the

feedback voltage. It has been found, however, that the device obtains its highest sensitivity when the phase displacement in the capacitor **22** is somewhat incomplete, so that the oscillator works at a frequency deviating somewhat from the resonance frequency of the series resonant circuit. The purpose of the resistor **18** is to add to the internal resistance of the tube to provide a series resistance sufficient for the phase displacement of the output voltage. The resistor **18** will even attenuate the output voltage of the amplifier so that the total gain in the oscillator equals one without any saturation in the amplifier. The sole purpose of resistor **17** is to pass direct current through the tube so that the correct working point on the tube characteristic is obtained and it may be substituted for instance by a suitable inductance.

Tests have shown that the arrangement according to Fig. 1 in spite of its simplicity has an excellent sensitivity to changes in the magnification factor of the resonant circuit arising when a substance to be tested is moved into the magnetic field of the coil **20** or the electric field of the capacitor **21**. The reason is that the feedback ratio of the oscillator is directly proportional to the magnification factor of the circuit, at the same time as the excellent stability in the cathode-connected amplifier makes it possible to let the oscillator work very near to its critical feedback ratio. Even if the arrangement according to Fig. 1 has excellent stability, it is often advantageous to stabilize the amplitude of oscillation so that slow changes in the characteristics of the oscillator does not disturb its function. In this way it is among other things possible to avoid adjustments of the device when the measuring member, i.e. the coil **20** or the capacitor **21**, changes its position in relation to the surroundings.

An arrangement satisfying this requirement is shown in Fig. 2, in which the numerals from Fig. 1 are used on equivalent elements. The pentode tube **10** together with the cathode resistor **17** and the capacitor **22** work as a cathode-follower and feeds the series-resonant circuit comprising the coil **20** and the capacitor **21**. The control grid **12** of the tube is connected to the coil **20** via a coupling capacitor **23**, which has for its purpose to separate the direct potential of the grid from ground. The suppressor grid **41** is connected to the cathode **11**, and the screen grid **42** is connected through a resistor **43** to the positive terminal of the direct current source **16** and through a capacitor **44** to the ground terminal **15**. The cathode resistor **18** in Fig. 1 is in Fig. 2 substituted by a plate resistor **19**, from which an alternating voltage is taken out via a coupling capacitor **27** to a rectifier of voltagedoubler type, comprising rectifier elements **31** and **32** together with a capacitor **33** being loaded by a resistor **34**. The voltage across the capacitor **33**, which is negative, is added to a positive voltage taken out from a potentiometer **36**, which in series with a resistor **37** is connected to the battery **16**. The voltage difference is fed to the grid **12** of the vacuum tube via a time delaying network comprising a series resistor **38** and a shunt capacitor **39**. A resistor **40** is connected between the grid **12** and the capacitor **39** in order that the capacitor shall not short-circuit the resonant circuit. The direct voltage fed to the grid is negative, and its magnitude is dependent on the amplitude of oscillation. An increase in the amplitude of oscillation causes an increased negative grid voltage, which in turn causes a decrease in the voltage gain in the tube. An increase or decrease in the amplitude of oscillation is thus counteracted, and through a suitable adjustment of the bias voltage from the potentiometer **36**, the oscillator may be made to work very near to its sensitivity maximum at all times. The time-delay network **38**, **39** makes, however, the stabilizing circuit ineffective when transient changes in the amplitude occurs. When a material to be tested passes through the electric or magnetic fields from the resonant circuit, a voltage surge is thus fed to the output terminal **25** via the capacitor **26** each time an inhomogeneity having loss properties differing from those of the base material passes the measuring device. This voltage surge may be measured or indicated by an instrument **45** or any other suitable device, so that a measurement or indication of the inhomogeneity is obtained.

As the tube is working as a cathode-follower the plate voltage of the tube has very small influence on the amplitude of oscillation in the oscillator, and this influence is reduced in the same degree as the amplification factor μ of the tube is increased. Across the plate resistor **19** it is therefore possible to obtain an amplified signal, and if the tube is a pentode, this amplification may be made very large. The necessary degree of amplitude stabilization thus can be obtained without the introduction of any separate amplifying stages and the output signal on the terminal **25** will also be so large that it directly can be fed to a measuring or indicating means, for instance a sensitive sudden change relay.

The embodiments of the invention shown are at present regarded as the most suitable, but the design of the oscillator may of course be varied within the range of the invention. For instance it is possible to utilize a transistor instead of the vacuum-tube shown.

I claim as my invention:

1. Means for examining a substance, comprising an oscillator having a series resonant tank circuit arranged to produce an electromagnetic field in the substance under test, said oscillator comprising a vacuum tube having a cathode, a control grid and a plate, a resistance means connected in series with said tube in such a way that it has a linearizing effect upon the plate-current-grid-voltage characteristic of said tube, an impedance means forming no part of said series resonant circuit and being connected in the cathode circuit of said tube, said series resonant tank circuit consisting of a coil and a capacitor being series connected across said impedance means, the junction point between said coil and said capacitor being connected to said control grid.

2. Means according to claim 1, in which said vacuum tube is a pentode.

3. Means according to claim 1, in which said impedance means is a capacitor shunted by a resistor.

4. Means according to claim 1, comprising means for measuring or indicating the amplitude of oscillation in said oscillator, connected across at least a part of said resistance means.

5. Means according to claim 1, in which said resistance means is connected in the cathode circuit of said tube.

6. Means according to claim 1, in which said resistance means is connected in the plate circuit of said tube.

7. Means according to claim 1, comprising a time-delayed amplitude-stabilizing feedback in said oscillator.

8. Means for examining a substance, comprising a vacuum tube having a cathode, a control grid and a plate, a source of direct current having a positive terminal and a negative terminal, a resistance means having a tap, connected between said negative terminal and said cathode, a coil and a first capacitor being series connected between said negative terminal and said tap on said resistance means, said control grid being connected to the junction point between said coil and said first capacitor, a second capacitor connected between said negative terminal and said tap, an output terminal connected to said cathode.

9. Means for examining a substance, comprising a vacuum tube having a cathode, a control grid and a plate, a source of direct current, a resistance means, an impedance means consisting of a resistor shunted by a capacitor, said tube and said direct current source being connected in series through said resistance means and said impedance means, said resistance means being connected to said plate, said impedance means being connected to said cathode, a series resonant circuit comprising a coil and a

capacitor shunting said impedance means, means including a coupling capacitor connecting said control grid to an intermediate point in said series resonant circuit, a rectifying means fed by an alternating voltage existing across said resistance means and having an output, a time delaying means including a series resistor and a shunt capacitor connecting said output to said control grid.

10. Means according to claim 9, in which a source of bias voltage for said control grid is series connected with said output from said rectifying means.

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