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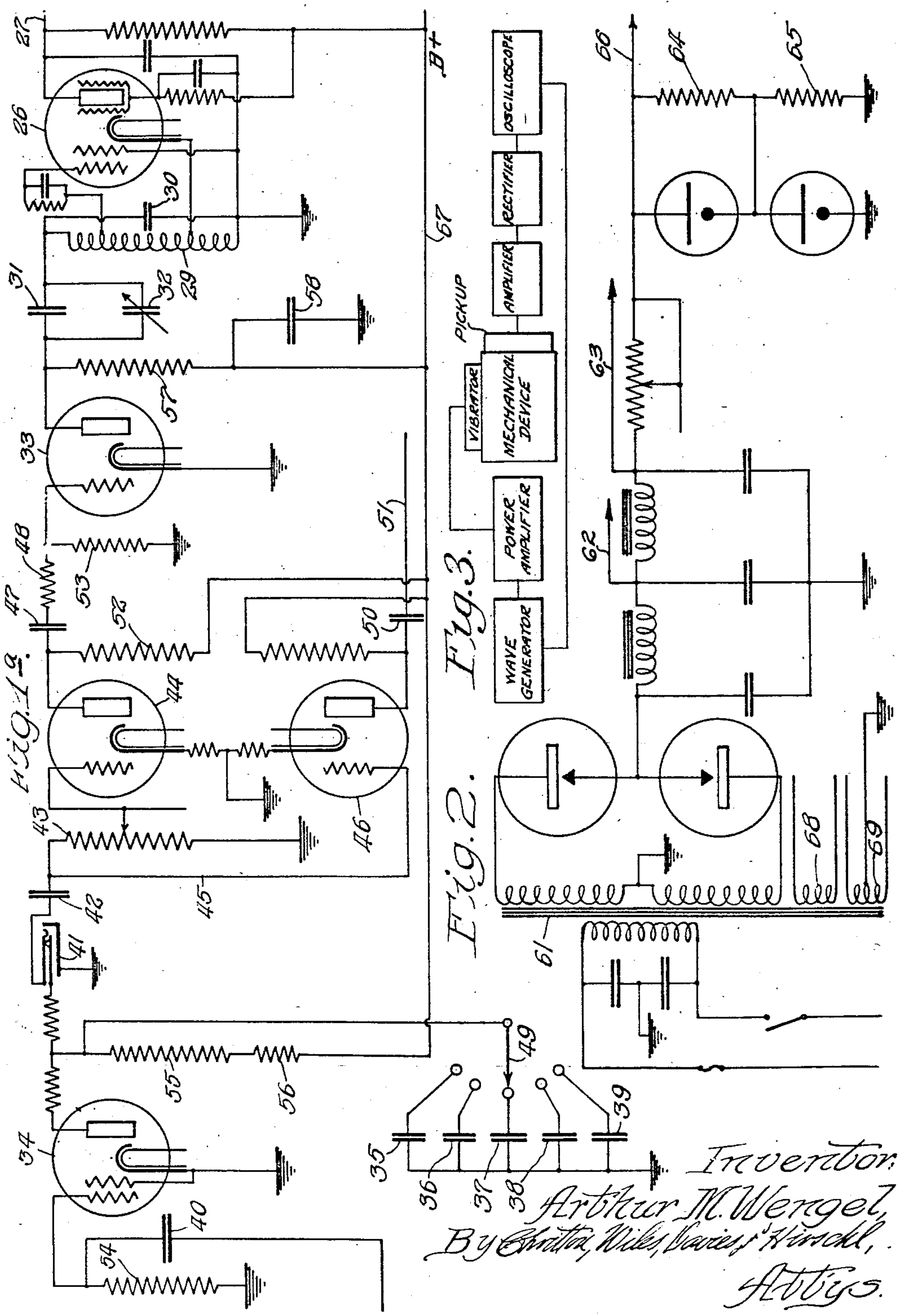
Sept. 11, 1945. A. M. WENGEL 2,384,716

FREQUENCY RESPONSIVE INDICATING APPARATUS

Filed March 14, 1941 2 Sheets-Sheet 1



Inventor:
Arthur M. Wengel,
By Chritton, Wiles, Davies & Hirschl,
Attys.

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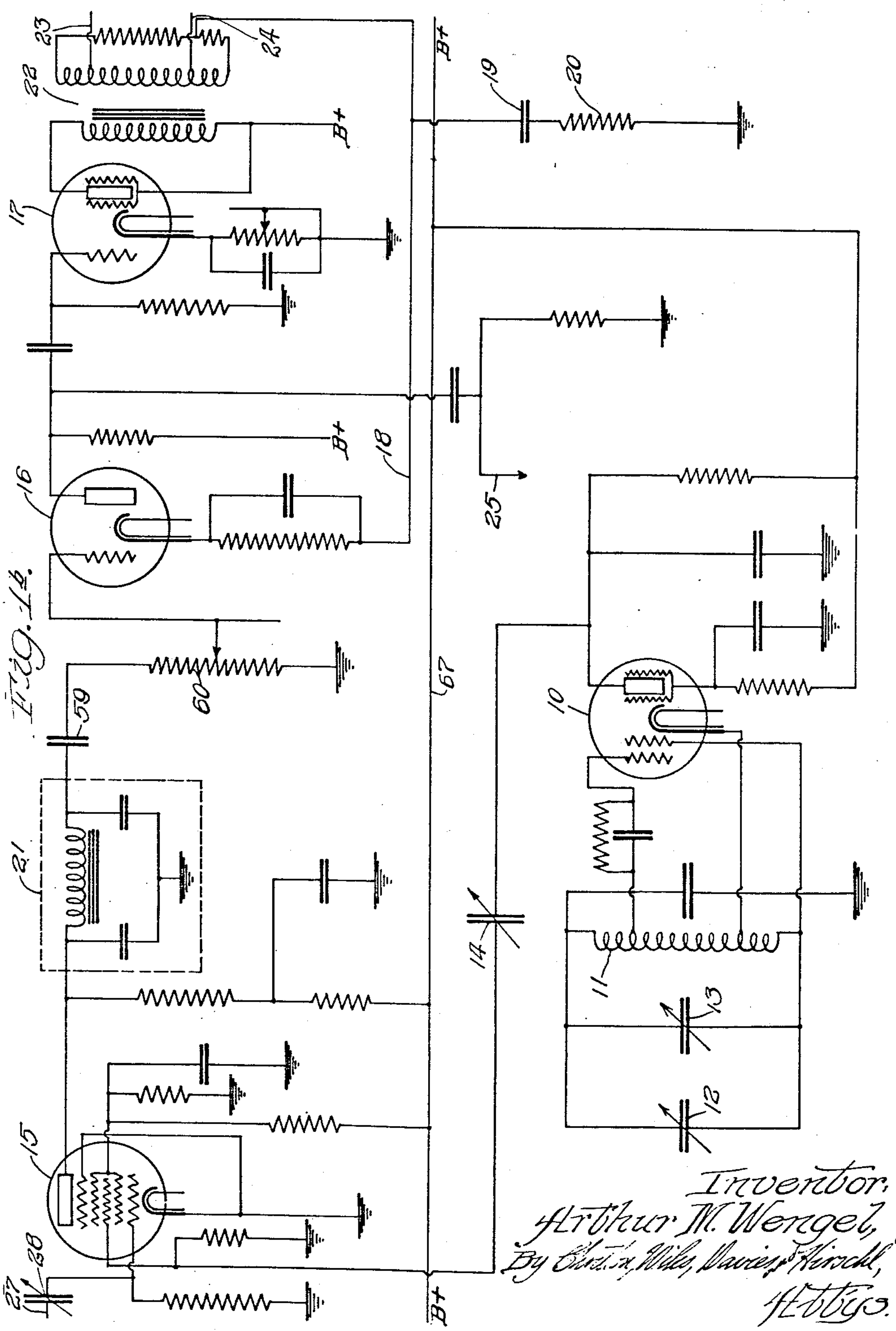

Fig. 1b.

Inventor.
Arthur M. Wengel,
By Chritton, Wiley, Davies & Hirschl,
Attys.

Patented Sept. 11, 1945 2,384,716

UNITED STATES PATENT OFFICE

2,384,716

FREQUENCY RESPONSIVE INDICATING APPARATUS

Arthur M. Wengel, Madison, Wis., assignor to Ray-O-Vac Company, a corporation of Wisconsin

Application March 14, 1941, Serial No. 383,431

2 Claims. (Cl. 73—67)

This invention relates to a frequency-responsive indicating apparatus, and more particularly to a generator for producing a wave output comprising a substantially uniform distribution of frequencies throughout a desired band, and to means for using the generator to provide an instantaneous determination of the frequency-response characteristic curve of a device being tested. This application is a continuation-in-part of my co-pending application, Serial No. 341,015, filed June 17, 1940, which issued as Patent No. 2,287,401 on June 23, 1942, which application was a continuation-in-part of my application, Serial No. 254,931, filed February 6, 1939, which issued as Patent No. 2,217,394 on October 8, 1940.

One feature of this invention is that it provides apparatus for generating a complex wave having a desired band width and frequency distribution; another feature of this invention is that the wave output generated by the apparatus regularly periodically varies in frequency through a desired frequency band; yet another feature of this application is that it provides apparatus enabling instantaneous determination of the frequency-response characteristic curve of a device being tested by making such curve visible on an oscilloscope; other features and advantages of this invention will be apparent from the following specification and the drawings, in which:

Figures 1ᵃ and 1ᵇ are a circuit diagram of a wave generator embodying my invention; Figure 2 is a circuit diagram of the power source for such a generator; Figure 3 is a block diagram of means for determining the vibratory response of a mechanical device.

In the particular embodiment of my wave generator illustrated herewith in Figures 1ᵃ and 1ᵇ, an oscillator generates a single wave, of a frequency determined by the elements in its tuning circuit, as for example one hundred kilocycles. Another oscillator is adapted to have the frequency generated by it vary through a band close to the frequency generated by the first oscillator, as for example through a band of ninety to one hundred kilocycles. This is accomplished electrically by frequency control means which is put through a rapid and regular periodic cycle, as for example sixty cycles per second, by a sweep oscillator. The outputs of the two oscillators are combined to produce a beat frequency wave regularly and periodically varying through the desired audio band.

This wave is then preferably passed through an amplifier which includes a low pass filter to remove the higher radio frequencies and leave only the beat note frequencies in the audible range. It will be apparent that the wave output comprises a substantially uniform distribution of frequencies of the same intensity. That is, if the variable oscillator swings from ninety to one hundred kilocycles sixty times a second, a few waves of each of the frequencies from substantially zero up to ten thousand cycles per second would be generated sixty times a second, so that waves of individual frequencies would not normally be distinguishable in the output. The sweep oscillator frequency can be made lower than normal audibility if desired; or it can be filtered out of the generator output by a rejection circuit in the amplifier sharply tuned to the sweep frequency.

Describing now in more detail the circuit arrangement of the wave generator, one of the oscillators is shown as comprising the tube **10** with its associated tuned circuit comprising the inductance **11** and a parallel capacity, here shown in the form of two variable condensers **12** and **13**. The circuit constants of the tuning circuit, of course, determine the frequency of oscillation; and they may be so chosen as to have this oscillator generate a frequency of one hundred kilocycles per second.

The plate circuit of the oscillator **10** is coupled through the coupling condenser **14** to one of the grids of the mixer tube **15**, comprising the first of a cascade of tubes in an amplifier. The other tubes of the amplifier are here indicated as **16** and **17**. The amplifier tubes are resistance coupled to provide an amplifier which is as free from distortion as possible, an inverse feed-back circuit through the wire **18**, and a circuit for dissipating some of the high frequencies to ground (comprising the condenser **19** and resistor **20**) also contributing to this result. The dissipating circuit is particularly important in this regard, since otherwise the amplifier would tend to have a rising characteristic curve amplifying the high frequencies more than the low and middle frequencies; and the addition of this dissipating circuit plays a major part in keeping the amplifier characteristic curve flat to a point as high as twenty thousand cycles. The amplifier also includes a low pass filter here identified as **21**, this filter serving to keep the radio frequency currents from passing through to the subsequent tubes of the amplifier, so that the output of the wave generator is comprised entirely of the desired audio frequency waves.

The output of the generator is developed across the secondary of the transformer here identified as 22, two different taps identified as 23 and 24 preferably being brought out from this secondary to provide output impedances of high and low value, as for example 8 ohms and 500 ohms. The output of the generator is, of course, developed between one or the other of these taps and ground. A portion of the current in the amplifier may be diverted through the wire 25 to an electronic tuning eye, as for example to the grid of a 6E5 tube. This provides ready means for determining zero beat conditions between the oscillator 10 and another oscillator to be described when their outputs are mixed in the tube 15, zero beat adjustment being effected by the condenser 13 which is of relatively small capacity. The condenser 12 is preferably manually adjustable in conjunction with a dial calibrated in oscillator frequency.

The input tube of the amplifier, the mixer tube 15, also has delivered to it the waves generated by a variable oscillator comprising the tube 26 and its associated circuits. It will be noted that the output of this tube, developed across a load resistor, is delivered through the wire 27 and variable coupling condenser 28 to another grid of the tube 15. The tuned circuit associated with the tube 26 to determine its frequency of oscillation includes the inductance 29 and a capacity which is the effective resultant of two capacities, one fixed and one variable. The fixed capacity is provided by the condenser 30, and the variable capacity by the fixed condenser 31 (shunted by a variable condenser 32 of very small capacity) which has its effectiveness varied by having its circuit to ground completed through the plate to cathode resistance of the tube 33. That is, variation of the plate to cathode space current resistance of the tube 33 varies the effectiveness of the capacity of the condensers 31 and 32, and thus varies the capacity in the tuned circuit determining the frequency of oscillation of the tube 26. Obviously, if the resistance of the interelement path in the tube 33 is quite high, the capacity of the condensers 31 and 32 is of little effect in the oscillator tuning circuit; whereas, as the interelement resistance of the tube 33 drops, the capacities of the two condensers 31 and 32 become more effective and the frequency generated by the oscillator 26 is varied. In operation the condenser 12 associated with the tube 10 would be adjusted to a desired point determining the low frequency boundary of the wave output which is to be generated; and then variation of the resistance of the tube 33 would cause the frequency generated by the oscillator 26 to vary through a band determined by the amount of resistance swing of the tube. The result of combining the outputs of the two oscillators in the mixer tube 15, therefore, is to provide a regularly periodically varying wave output which contains partials of the individual frequencies through a desired band.

The resistance interposed by the plate to cathode path in the tube 33 is, of course, a direct function of the voltage applied to the grid of that tube, so long as care is taken to stay on a straight portion of the tube characteristic curve. Means is provided for regularly periodically varying the grid voltage between desired values, and this will now be more fully described.

At the furthest lefthand side of Figure 1a is a tube here identified as 34, which may be a type 2051, so connected as to act as a sawtooth generator. The frequency of the impulses delivered by this tube 34 are controlled by the value of the condenser charged and discharged by the tube, and provision is here made to selectively use any of a plurality of condensers. The condenser 35, for example, may be of .1 microfarad capacity and intended to provide a sawtooth frequency of sixty cycles per second and the condensers 36, 37, 38 and 39 may have capacities respectively of .25, .50, .75, and 2.0 microfarads to provide frequencies of 30, 15, 10 and 5 cycles per second. In order to insure maintenance of the desired frequency I couple the grid of the tube 34, through a coupling condenser 40, to some source of standard known frequency derived from the commercial power lines, which may be either sixty cycles or some multiple or submultiple thereof. This initiates discharge of the condenser at the desired time and maintains the proper frequency. The output of the sawtooth generator 34 is delivered through coupling resistors, a jack 41, a coupling condenser 42, and a potentiometer 43 to the grid of a buffer tube 44. A lead 45 is tapped off ahead of the potentiometer to energize the grid of another buffer tube 46. These tubes may be in the same envelope if desired, as for example a tube of the 7F7 type.

The output circuit of the buffer tube 44 is coupled through a condenser 47 and resistor 48 to the grid of the control tube 33, so that the grid of this tube has applied to it a voltage which varies between a minimum value and a maximum value determined by the setting of the potentiometer 43, and with a frequency determined by the setting of the control switch 49 associated with the condensers 35 to 39. The jack 41 enables another voltage to be used to energize the control tube if desired, as for example conventional sixty-cycle current. The output of the buffer tube 46 is passed through the coupling condenser 50 and the wire 51 to an oscilloscope when it is desired to lock the horizontal sweep of the oscilloscope into step with the frequency of the sawtooth generator 34, for purposes which will be described hereafter. The values of the condenser 47 and resistor 48 are critical if the tube 33 is to be kept on a straight portion of its characteristic curve. These are here disclosed as being of .005 microfarad capacity and 45,000 ohms resistance, in conjunction with a 10,000-ohm output resistor 52 for the tube 44 and a 10-megohm input resistor 53 for the tube 33, where this latter tube is of the 6J5 type.

It will be apparent that if the tube 26 generates a frequency varying regularly between 102 kilocycles and 112 kilocycles, and the frequency of the tube 10 is adjusted by the condenser 12 to be 100 kilocycles, the resultant wave output of the generator will vary regularly and periodically from two to twelve thousand cycles per second at a rate dependent upon the frequency of the sawtooth generator 34. The purpose of the tube 33 of course, is to provide a readily variable pure resistance in series with one of the capacities of the tuning circuit of the oscillator 26, so that variation of this resistance varies the effectiveness of the capacity and thus the frequency developed by the oscillator. The tube 34 provides straight line variation of the plate to cathode resistance of the tube 33 at a frequency desired, and as determined by the setting of the switch 49. The buffer tubes, of course, merely operate to electrically isolate the sawtooth generator from the other portions of the circuit, these tubes not giving any amplification.

While the majority of the circuit constants follow conventional amplifier and oscillator practice, a few should be specifically mentioned. The input resistor **54** of the tube **34** should be of about one megohm resistance where three volts synchronizing voltage are applied through the condenser **40** of one-half microfarad capacity; and the output resistors **55** and **56** should be one megohm and one-quarter megohm, respectively. The potentiometer **43** preferably has a value of about 25,000 ohms in conjunction with the buffer tubes of the type mentioned, and the plate resistor **57** of the control tube **33** should have a value of about 35,000 ohms and be used in conjunction with a condenser **58** of about 40 microfarads. The mixer tube **15** is preferably of the 6L7 type, and the tubes **16** and **17** may be of the 6C5 and 6V6 type, with appropriate resistance coupling values. It will be noted that the circuit from the low pass filter **21** to the tube **16** is completed through a coupling condenser **59** and a potentiometer **60**, which may have a value of .1 microfarad and 250,000 ohms respectively. The potentiometer **60** should preferably be calibrated directly in output intensity of the wave. The tube **10** is preferably of the 6SJ7 type. The inductances and capacities of the tuned circuits associated with both oscillators are chosen, of course, in accordance with the frequencies desired.

Referring now more particularly to Figure 2, a substantially conventional power supply to provide the actuating voltages for the wave generator is shown. Standard sixty-cycle alternating current may be supplied to the primary of transformer **61**, the secondary developing a voltage through two rectifiers of a full wave rectifier tube such as the 5Z3 on a filter circuit. The lead **62** is tapped off to provide plate voltage for the tube **17**; and a tap or lead **63** may be taken off to provide plate voltage for the first audio amplifying tube **16**. The output of the filter is also developed across a voltage bleeder resistor comprising the two resistors **64** and **65** shunted by voltage regulating tubes. Each of these resistors should have a value of at least 50,000 ohms and preferably in the neighborhood of one megohm. The output voltage developed across these resistors is applied through the lead **66** to the B+ bus wire **67**, which delivers plate voltage to all of the tubes except the tubes **16** and **17**. Filament and heater voltages are secured in conventional manner from the additional secondaries **68** and **69** of the transformer **61**.

A very important usage of my wave generator is in connection with the arrangement illustrated in Figure 3. In this arrangement the output of the wave generator is delivered to a power amplifier to build up substantial power, and then this is used to drive a vibrator, preferably of the dynamic type. The vibrator is fastened to some appropriate part of a mechanical device, as the frame of an airplane wing, so that mechanical vibratory impulses of all frequencies through a desired band are delivered to the frame. If there are any parts of the frame particularly sensitive to a given frequency, this will show up at once if a pick-up device is run along different parts of the frame. The pick-up device may be connected through an amplifier and rectifier to an oscilloscope synchronized with the wave generator, and the response curve visible on the sight screen of the oscilloscope will vary as the pick-up is moved to various parts of the mechanical device. Obviously, if the pick-up is placed on the antinode of a member having a natural frequency within the wave band being developed by the wave generator, a very sharp response at this frequency will be indicated upon the oscilloscope. In this manner the arrangement may be used to determine vibration points which should be damped or tied down by struts or the like, if frequencies destructive to the wing frame are to be eliminated.

While I have shown and described an embodiment of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims.

I claim:

1. Apparatus of the character described for making a vibration test of a mechanical device, including: vibrator means adapted to be excited by electrical energy and to mechanically vibrate said device; pick-up means adapted to be excited by mechanical vibrations set up in a portion of said device; indicating means actuated by said pick-up means; and means for generating and delivering to said vibrator means energy in the form of cyclically recurring bands of frequencies with the duration of a cycle and the interval between cycles being so short that the effect on the device is that of practically continuous excitation by the simultaneous application thereto of a multiplicity of frequencies lying within a band of frequencies, whereby the indicating means responds to the resonant frequency of the selected portion of the device exciting the pick-up means.

2. Apparatus of the character claim in claim 1, wherein the pick-up is of relatively small size compared to the device being tested.

ARTHUR M. WENGEL.

CERTIFICATE OF CORRECTION.

Patent No. 2,384,716. September 11, 1945.

ARTHUR M. WENGEL.

13/67

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 1-2, for "frequency-responsive" read --frequency-response--; line 35, after the semicolon and before "Figure" insert --and--; page 2, second column, line 33, after "varies" insert --regularly--; page 3, second column, line 55, claim 2, for "claim in" read --claimed in--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22nd day of January, A. D. 1946.

Leslie Frazer

(Seal) First Assistant Commissioner of Patents.