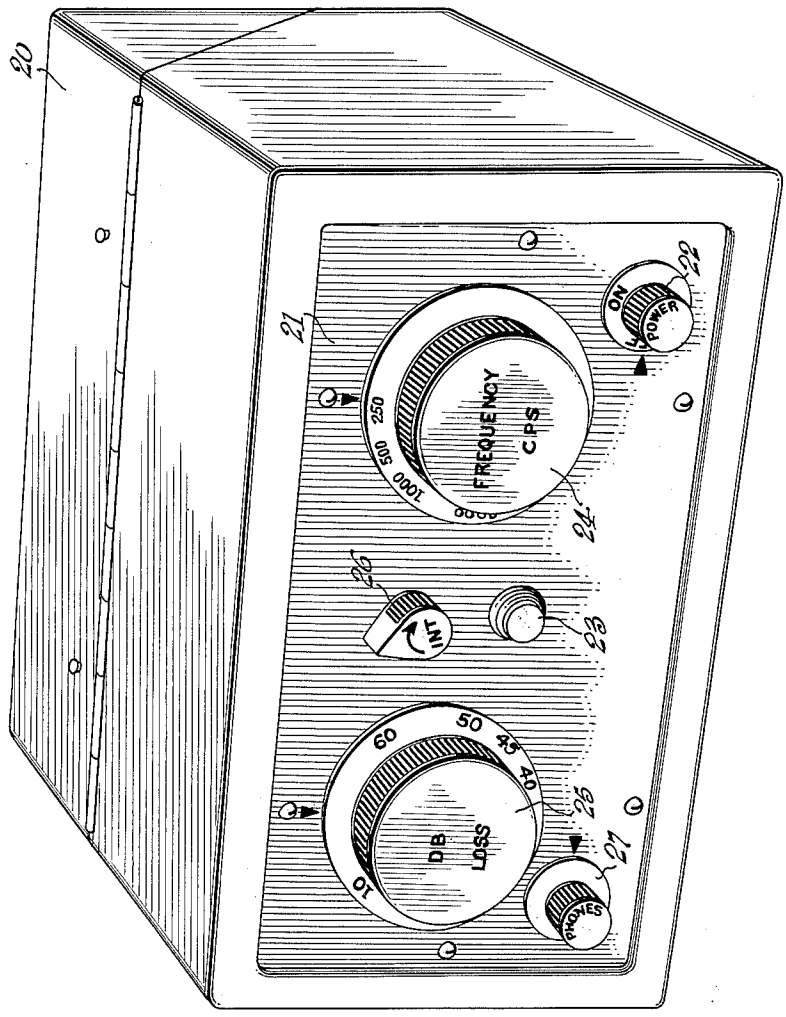
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AUDIOMETER

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Fig. 1.



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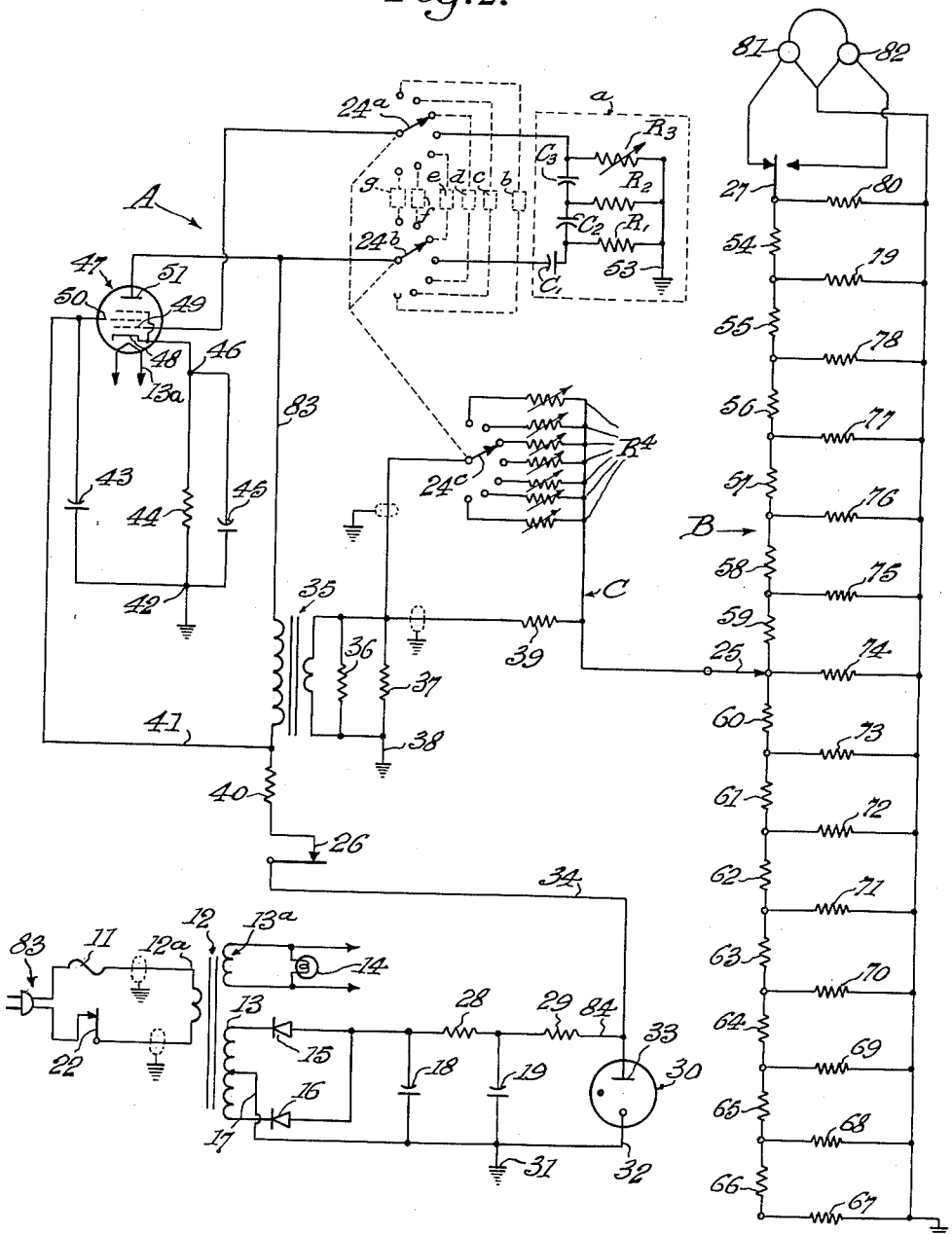
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AUDIOMETER

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Fig. 2.



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3,054,855

AUDIOMETER

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to improvements in the art of audiometers and relates more specifically to a portable audiometer of the sweep-frequency type which employs an electrical circuit having a phase-shift oscillator including a frequency determining phase shifting network, audio signal attenuator means, automatic impedance matching network for each step of audio frequency of output signal, and a variable resistive calibrating means all energized by a circuit comprising a full wave rectifier joined by a double filter section to an output voltage regulation tube.

A satisfactory audiometer must enable the physician to accurately and satisfactorily measure the hearing sensitivity and acuity of an individual patient over the principal frequency range of audible sound. The frequency range which is important for hearing, and in which the range of hearing sensitivity is greatest lies between substantially 100 and 8000 cycles per second, and an audiometer for determining hearing impairments of deafened persons should be able to measure eighty percent loss of hearing for this range of frequency. In addition, a satisfactory audiometer should be able to measure steps of audible or sound frequency within the testing range above a pure tone and the intensity of the tone should be accurately measurable. A change of sound intensity by one decibel is substantially the minimum change detectible by the human ear. However, because of the uncertainty of judgment of an average individual, one decibel (unit of hearing loss) change in sound intensity is of no great significance. However, for most practical purposes in testing the hearing of a deafened individual, it is sufficient to test the individual's hearing with an audiometer capable of producing good tones at frequency steps of 250, 500, 1000, 2,000, 3000, 4000, and 7000 cycles per second. However, pure tones at frequency steps which are an octave apart and extend over a range from 128 to 8192 cycles per second and which are capable of determining one's hearing ability in steps of five decibels may be used if desired.

The improvement of this invention over the prior art resides in the design of the new circuit configuration, the employment of a minimum of conventional tube circuit components, employment of a one tube phase-shift oscillator, means to vary the step frequency of the oscillator, automatic impedance matching means and means to quickly and reliably calibrate the device; a full-wave rectifier power circuit properly filtered and controlled by a linear type of voltage regulator tube, the output of which energizes a phase-shift oscillator which in turn is coupled by a low impedance matching transformer and network selectively and variably coupled to a ladder type of sensitivity attenuator calibrated in decibels; capability of the device to be used selectively with air conduction or bone conduction receivers incorporated in an economical, easy to manufacture, and portable hearing testing device which produces reliable, stable, and critical end results in the examining and diagnosing of the impaired hearing of individual patients by a physician.

It is a primary object of this invention to provide an audiometer embodying a phase-shift oscillator including a frequency determining phase-shift network suitable for diagnostic and screening purposes which may be

quickly and accurately attenuated within an audio threshold at a predetermined frequency by a multiple choice of values in a fixed calibrating circuit.

It is another object of this invention to provide a method of comparing the relative hearing acuity of a patient before and after being fitted with a hearing aid device under the same external conditions.

It is a still further object of this invention to provide an audiometer having excellent stability and wave shape.

It is another object of this invention to provide an audiometer of dependable, simple, and efficient design having a unidirectional full-wave rectification means, voltage control means, and a stable one tube variable oscillator means which may be light, portable, and easy to manufacture at an economical cost.

It is a further object of this invention to provide a novel arrangement of network components and threshold level resistors on multi-deck switches for efficient manufacture and utilization of space.

It is another object of this invention to provide a low impedance termination of the oscillator output circuit while the frequency of the oscillator is varied over a broad frequency range by termination of ganged voltage dividers of the attenuator at various frequency and audio threshold levels without substantially varying the inductive coupling during the attenuation of the phase-shift oscillator and the intensity of audio threshold in decibels at a given frequency.

The foregoing and other objects of the invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawings, wherein—

FIG. 1 is a perspective exterior view of the housing enclosing the circuit and control means of instant device; and

FIG. 2 is a circuit diagram of the audiometer.

FIG. 1 shows a suitable housing for the apparatus comprising a portable cabinet **20** having a front panel **21** on which are mounted a power switch **22**, pilot or telltale light assembly **23**, frequency step control dial **24**, audio signal attenuator or intensity dial **25** graduated in decibels, oscillator energizing switch **26** and selective earphone switch **27**.

FIG. 2 illustrates the novel circuitry configuration of the present invention which is energized by an A.-C. plug-in full-wave rectifier power unit consisting of a shielded power transformer **12**, lead and plug-in **83** and complementary rectifiers **15** and **16**; filter circuit comprising condensers **18** and **19**, resistors **28** and **29** are operably connected by leads **32** and **84** to voltage regulator tube **30** and ground **31**. The primary winding of power transformer **12** consists of inductive coupling **12*a*** with proper shielding and grounding as shown.

Member **11** denotes a safety fuse and member **22** an on-and-off switch or circuit closing device. Rectifiers **15** and **16** and center-tapped lead **17** are operably connected to secondary inductive coupling **13**, as shown, to obtain a fullwave form of current supply. Rectifiers **15** and **16** may be of the selenium or other suitable type which require no filament voltage to energize them, are economical in cost, and occupy little space. Secondary winding or inductive coupling **13*a*** furnishes A.-C. current to energize pilot or telltale light **14** and furnish filament voltage to pentode tube **47**. The current and output voltage of the power unit is unidirectional containing a minimum of ripple voltage approximating a dependable A.-C. current supply with a substantial constant voltage potential to the phase-shift oscillator network A which is inductively coupled by transformer **35** to resistors **36** and **37** and connected by variable switch means **25** through resistor **39** to signal attenuator network B and conductive receivers or earphones **81** and **82**. The output of VR (voltage regulator) tube **30** is operably connected by lead

34, as shown, through switch means 26 and resistor means 40 to lead 41 and primary winding means of shielded signal output transformer 35 connected by lead 83 to anode 51 of pentode tube 47 as plate voltage. The fixed bias of cathode 48 of tube 47 is obtained by common lead connection 46 connecting in parallel circuit arrangement resistance 44 and condenser 45 between electrode means 48 and ground connection 42. The frequency of audio signal output of oscillator A is varied in steps of frequency by condensers C_1, C_2 and C_3 and resistors R_1, R_2 and R_3 having selected values as given in the following table:

Audio Frequency, Cycles/sec.	C_1 mmf.	C_2 mmf.	C_3 mmf.	R_1 ohms	R_2 ohms	R_3 ohms	R_4 ohms
250	200	510	510	1.2 meg.	1 meg.	1 meg.	120
500	330	330	300	680K	270K	680K	560
1,000	510	200	200	150K	470K	270K	1,800
2,000	330	330	330	100K	120K	120K	1,500
3,000	510	330	510	56K	68K	47K	4,700
4,000	510	330	510	27K	47K	68K	4,700
7,000	330	330	510	27K	33K	27K	1,000

It is to be understood that this invention is not limited to the frequencies shown in the above table, as it is well within the ability of one skilled in the art to practice this invention by using other desirable frequencies. Dotted block diagrams *a, b, c, d, e, f* and *g*, as shown, illustrate a resistance capacitance phase-shifting network connected between the output and the input of the tube 47. The network is so proportioned that the feedback between the plate and grid terminals is in phase at the frequency of oscillation desired. An advantage of using this type of oscillator is that it is economical to manufacture, uses only one electronic tube, and results in a portable and compact instrument. When the gain of the pentode is adjusted either manually or by an automatic amplitude-control circuit, barely to maintain proper oscillations (not overloaded), almost a pure sine-wave output audio signal is obtained with good frequency stability. The phase-shift oscillator means A is particularly stable and suitable for operation at fixed frequency steps and probably represents the simplest satisfactory audio oscillator for use with an audiometer. The circuitry orientation of block diagrams *b, c, d, e, f* and *g* is as shown in enlarged block diagram *a*, which shows the resistance capacitance phase-shifting network comprising resistors R_1, R_2 and R_3 and condensors C_1, C_2 and C_3. Each step of frequency of oscillator A has a separate network as designated by dotted block diagrams *a, b, c, d, e, f* and *g* in which each block diagram is selectively connected by manually operated and mechanically ganged switches as multi-decked switches comprising switch means *24a* and *24b* connected to plate 51 and grid 49 of tube 47, as shown. Grid 50 of tube 47 is operably connected by condenser 43 to ground terminal point 42. Electronic tubes 30 and 47 are shielded to attenuate or eliminate radiation, hum, and noise pickup arising from causes external to the tubes which act either upon the tubes or upon the components of the circuit. The output of oscillator network A is inductively coupled (to insure safety of patient from current shock) by transformer 35 to voltage divider and impedance matching circuit C comprising ground connection 38, resistances 36, 37, 39, attenuator B and R_4. Each value of variable resistance R_4 is manually preselected by switch *24c* mechanically ganged to switches *24a* and *24b*. Output transformer 35 inductively couples electrically the output signal of tube 47 to variable switch means 25 which may be selectively connected to the various sections of attenuator network B to selectively vary in decibel units the intensity of the audio signal to switch 27 which selectively connects the audio signal to receivers 81 and 82 during an auditory test for impairment of human hearing.

The circuit of this invention has a variable low impedance termination to effect broad-band response in audio signal output of transformer 35 to obtain optimum impedance match of output transformer 35 to attenuator B. Transformer 35 may be of a shielded inexpensive type. Variable resistances R_3 and R_4 are sub-miniature potentiometers and provide means for accurate and rapid calibration of frequency and threshold audio signal levels whereby an optimum impedance match of signal between networks A, B, and resistors 36, 37 and 39 is reflected to plate 51 of oscillator tube 47 for each step of frequency of the audio frequency signal.

Resistances 36 and 37 are part of a voltage divider and impedance matching network constituting resistances 36, 37, 39, R_4 and attenuator B. R_4 consists of a plurality of step resistances, each of which are a sub-miniature potentiometer. R_4 is present in the calibration procedure to establish the threshold level for each frequency and manually varied by switch *24c* for proper impedance match of coupling of oscillator A to attenuator network B for each frequency step of signal output of oscillator A by switch *24c* being mechanically ganged to switch means *24a* and *24b* as multi-deck switch 24 to insure that R_4 is preset in the calibration procedure to establish the threshold level for each frequency and manually and selectively varied for each proper threshold frequency level of signal without affecting the matching of transformer 35 in the circuit. The potentiometers R_4 act as isolators between the load resistors 36, 37 and the attenuator network B and maintain stability of the oscillations as well as establishing levels above threshold of hearing.

In the practice of this invention resistances 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66 and 67 may have an ohmic value of 5.1 ohms; resistances 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79 and 80 may have an ohmic value of 15 ohms; condenser 43 has a capacitor value of 4 mfd.; resistance 44 has a resistive value of 220 ohms; condenser 45 has a capacitator value of 25 mfd. with a working voltage of 25 volts; resistor 36 has an ohmic value of 4.7 ohms; resistor 37 has an ohmic value of 4.7 ohms; resistor 39 may have an ohmic value of 2700 ohms; condensers 18 and 19 may each have a capacitator value of 40 mfd. with a working voltage of 450 volts; resistance 28 may have an ohmic value of 750 ohms with a 10 watt output rating; resistance 29 may have an ohmic value of 3000 ohms with a 10 watt output rating; tube 30 may be a VR (voltage regulator) tube of type OA2 and pentode tube 47 may be a beam power amplifier tube of type 6005. However, it is to be understood that this invention is not restricted to the above values as it is well within the ability of one skilled in the art to use other values without departing from the spirit and scope of the invention. Audio signal receivers 81 and 82 may be either of the bone conducting or air conducting type. Switches *24a*, *24b* and *24c* are mechanically ganged together for manual operation with dial 24 shown in FIG. 1. The aforementioned impedance matching circuit and rectifier circuit are shielded and grounded, as shown in FIG. 2, to reduce the harmful effect of external hum or interference in audio receivers 81 and 82.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention.

Having thus described my invention, what I claim as new and wish to secure by Letters Patent is:

1. An audiometer comprising energizing means, phase-shift oscillator means connected to the output of said energizing means and including a plurality of frequency determining network circuits, each said network circuit having a variable adjusting means and variable switch means for selectively connecting a frequency determining network to said oscillator, audio transformer means connected to the oscillator means, a plurality of impedance matching network means selectively connected to the output of said transformer means including variable resistive

adjusting means, a voltage divider means, and step attenuating resistive network means, switch means interconnecting said frequency determining and impedance matching networks to selectively connect the necessary impedance matching network with a selected frequency determining network, said voltage divider means including series circuit means for interconnecting said attenuator means to said transformer output for substantially isolating varying attenuator load reflections from said oscillator transformer output, and earphone means connected to the output of said attenuation means for determining the hearing frequency of partially deaf individuals.

2. An audiometer for determining the hearing impairments of personnel comprising an energizing circuit, a phase-shift oscillator circuit including a separate frequency determining circuit for each frequency and having an audio signal output, said oscillator circuit being selectively and operably connected to the output of said energizing circuit, variable impedance matching means inductively coupled by transformer output means to the output of said oscillator circuit, adjusting means included in each frequency determining circuit for the oscillator circuit, said variable impedance matching means cooperating by mechanical coupling with said adjusting means of said oscillator circuit, a plurality of conductive earphone receivers, variable resistive type attenuation circuit means connecting said variable impedance means to said receivers, voltage divider means including series circuit means for interconnecting said attenuator circuit means to said transformer output for substantially isolating varying attenuator load reflections from said oscillator circuit and switch means selectively cooperating with said attenuator means to vary the intensity of said audio signal to said conductive earphone receivers.

3. An audiometer comprising an energizing circuit, phase-shift oscillator means including pentode tube means with RC network circuit means providing a plurality of variable frequency steps connected between the input electrode means and output electrode means of said pentode tube means, said network permitting energy feedback between the anode and gride terminals of said tube, said oscillation circuit being selectively and operably connected to the output of said energizing circuit, variable impedance matching means inductively coupled by transformer output means to the output of said oscillator circuit, a first adjusting means included in said RC network for adjusting the oscillator circuit, a second adjusting means in the impedance matching circuit being mechanically and selectively coupled to first adjusting means included in said RC network of said oscillator circuit, a plurality of conductive earphone receivers having selective switch means, variable resistive attenuation circuit means, voltage divider means including series circuit means for interconnecting said attenuator circuit means to said transformer output for substantially isolating varying attenuator load reflections from said oscillator circuit, said attenuator circuit means including means for selectively connecting said variable impedance matching means to said receivers to vary the intensity of said audio output signal in decibel units to said conductive earphone receivers.

4. An audiometer comprising an energizing circuit, a phase-shift oscillator including pentode tube means having connected thereto resistive-capacitive network circuit means comprising a plurality of frequency determining circuits selectively connected between the cathode electrode means and anode electrode means of said pentode tube means, said network permitting energy feedback between anode and grid terminals of said tube means in a predetermined phase relationship at the frequency of oscillation, said oscillator circuit being selectively and operably connected to the output of said energizing circuit, a first variable resistive adjusting means included in each of said frequency determining circuits selectively connected to said oscillator circuit, variable impedance matching network circuit means including a second variable resistive adjusting means, audio transformer coupled output means inductively connecting said impedance matching network to the output of said oscillator circuit means, variable resistance attenuation circuit means, voltage divider means including series circuit means for interconnecting said attenuator circuit means to said transformer coupled output means for substantially isolating varying attenuator load reflections from said oscillator circuit, a plurality of conductive earphone receivers including selective switch means, said variable resistive attenuation circuit means including means for selectively connecting said variable impedance network to said audio receivers including switching means whereby the intensity of said audio signal is selectively varied in decibel units to said receivers.

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