

PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in Apparatus for Measuring, or for Measuring and Compensating for, Hearing-loss

I, GERARD MICHAEL HORVITCH, of 120b, Pritchard Street, Johannesburg, Transvaal, Union of South Africa, a British Subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to apparatus for measuring and compensating for, hearing-loss in the case of deaf persons and others with imperfect hearing.

Apparatus for the measurement of hearing-loss (sometimes referred to as "audiometers") comprise, in general, an audio-frequency generator fitted with a variable frequency control and with a variable volume control, and are connected in circuit with a telephone receiver or headphone. In using the apparatus, the usual procedure is to test the patient by signals for the desired range of audio-frequency, increasing the intensity or volume of tone in each case until the note is heard by the patient. Upon hearing the note, the patient customarily gives a signal by means of a push-button controlling a signal lamp. The intensity is then reduced by operating the volume control until the patient no longer hears the note which may be ascertained by his failure to signal when the tone is turned on. In this manner, the exact level of hearing-loss of the patient can be plotted or marked, for each frequency selected, on a chart (sometimes known as an "audiogram") in which hearing-loss in decibels is marked on a vertical axis against frequency in cycles per second marked along a horizontal axis. The graph or curve drawn through the points so plotted indicates the threshold of hearing for the patient, and renders possible the recommendation of a proper electrical or acoustical hearing aid for the patient's use.

With the existing apparatus, the diagnosis of the hearing-loss tends to be

rendered inaccurate by reason, on the one hand, of the patient not giving the signal when he first hears the tone exactly at the correct moment and by reason, on the other hand, of the otologist or person in charge not marking the corresponding point on the chart or audiogram at the correct position. In other words, the plotting of the levels of hearing-loss at the various audio-frequencies is, in the case of the existing meters, a procedure which is open to the occurrence of inaccuracies through the fact that the giving of the signal of incipient hearing or the ascertainment of the level of hearing-loss depends to an unduly large extent on the voluntary reactions of the patient himself, and on the alertness and promptitude of reaction of the otologist.

One object of the present invention is to provide an apparatus which will overcome, and minimise as far as possible this disadvantage and render possible more accurate recording of the hearing-loss levels or audiographic curve. A further object of the invention is to provide an apparatus for measuring, or for measuring and compensating for, hearing-loss in which the power passed to one or more receivers, head-phones vibrators or like devices can be made always to agree with the volume control setting on the input side of the apparatus, so as to enhance the accuracy of measurement and/or compensation of hearing-loss, irrespective of the input level.

According to the invention, I provide an apparatus of the type stated in which the plotting or marking of the levels of hearing-loss at selected frequencies is made directly on the chart or audiogram by a marking device operable by means adapted to be actuated by a neuro-reaction meter, such as a neuro-voltmeter or lie-detector, applied to the patient, so that the marking device will be caused to perforate or mark the chart or audiogram automatically in accordance with

variation in the nervous condition of the patient brought about by his first hearing the note transmitted to the telephone receiver, head-phones or receiving device.

- 5 The electronic test hereby made is preferably carried out on the same chart or audiogram as that on which is recorded the test and audiogram obtained by
10 voluntary or manual operation of the marking member by the patient. In consequence of the fact that the nervous condition of a deaf person is generally particularly sensitive, as compared with persons with normal hearing, the elec-
15 tronic test just referred to operates as a specially efficient check upon the accuracy of the graph of hearing-loss obtained by the test in which the deaf person partici-
20 pates by his own voluntary or manual operation of the push button, or the like, controlling the marking member.

The neuro-meter is coupled to a high-grain amplifier whereby the minute currents produced in the meter by the
25 nervous reaction of the patient are sufficiently amplified to enable a switch in the solenoid or equivalent circuit of the punch or marking member to be operated by a relay.

- 30 According to another feature of the invention, I provide an apparatus of the type stated which comprises an input circuit having a variable frequency generator adapted to generate thermionic
35 signals of individual frequencies, a microphone, phonograph, radio receiver or other means adapted to produce thermionic voice, music or other signals of complex frequencies, a volume control set,
40 switch or like means for connecting said volume control set to either said generator or said microphone, phonograph or the like, means whereby the intensity or volume of the signals produced thereby
45 may be varied, and an output circuit having one or more telephone receivers or other receiving devices, means for transmitting the aforesaid thermionic signal or signals to the one or more telephone
50 receivers or devices, and a volume level indicator which comprises a rectifying valve and a D.C. meter which is calibrated to suit the setting of the volume control set when the apparatus is per-
55 fectly balanced and which enables the signals passed to the one or more telephone receivers or devices always to agree with the setting of the volume control set in the input circuit in respect of
60 their intensity or volume.

Preferably, I provide in the output circuit, and/or in the individual receiving circuits, means for passing or rejecting
65 selected frequency components trans- mitted to the one or more receiving

devices, and/or attenuator means for controlling the intensity of the said components as fed to the said device or devices.

As a receiving device, I may employ, in the case of wholly deaf persons, a pitch indicator.

An apparatus embodying the invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a simple circuit diagram of the apparatus;

Fig. 2 is an elevation of an audiographic marking device, as embodied in my apparatus, parts being broken away for illustration purposes.

Referring to the drawings:—

The apparatus comprises a variable frequency generator which includes variable inductances 1, 2, mechanically coupled to a frequency impulse transmitter 3, the inductance 1 and 2 being connected to the anode or plate, and to the grid, respectively, of a tube 4. A control unit 200 with a gas tube and relay serves to cause regular intermittent operation of the generator 1, 2 and render the tone more perceptible. A volume correction adjuster 5 is connected to the anode circuit of the tube 4 and has its output lead 6 connected to a switch terminal 7. The frequency impulse transmitter 3 is in circuit through a stabilising resistance 8 with the grid of a gas tube control 9, the anode of which is connected by a lead 10 with the input terminal of a rotary relay 11. As illustrated, the transmitter 3 consists of a series of contacts 3^a and a movable contact arm 3^b mechanically coupled to the control member of the inductance 1, 2, the arrangement being such that as the frequency is altered, the contact arm 3^b successively engages the contacts 3^a, thereby transmitting impulses to the relay 11, which is energised in a number of successive steps each corresponding to a sub-division (frequency ordinate) 100 of a chart 98 (Fig. 2) hereinafter described. The number of contacts 3^a corresponds to the number of sub-divisions 100 of the chart. A volume impulse transmitter 12^b is connected to the grid of a gas tube control 13, the anode of which is connected by a lead 14^a to the input terminal of a volume rotary relay 14. The volume impulse transmitter 12^b consists of a series of contacts 12^c and a movable contact arm 12^d mechanically coupled to the control member of the volume control 12^a, the arrangement being such that, as the volume is altered, the contact arm 12^d engages the contacts 12^c, thereby transmitting impulses to the relay 14 which is thereby energised in a number of succes- 130

sive steps each corresponding to a subdivision (hearing-loss line) 101 of the chart 98 (Fig. 2) aforesaid. The number of contacts 12^c corresponds to the number of divisions 101 of the chart. The terminal 7 of the frequency generator 1, 2 is adapted to be connected to the volume control 12^a by a switch arm 15.

A D.C. power supply 16 is connected to the volume impulse transmitted 12^b through a lead 17 and stabilising resistance 18. The power supply 16 is also connected to the frequency generator 1, 2 through a lead 19. The armature or solenoid 20 of a punch (hereinafter referred to) has its actuating coil 21 connected to the power supply 16 through a lead 22 and is connected in circuit with a manually operable switch 23, which is shunted by contacts 24 controlled by a relay 25. The relay 25 is connected in circuit with a high gain amplifier and control tube 26 which is coupled by a line 27 with a neuro-voltmeter 28.

A microphone 29 is connected to the grid of an amplifier and control tube 30, the anode of which is connected through a condenser 31 and volume correction adjuster 32 to a terminal 33. Similarly, a phonograph 34 is included in the grid circuit of an amplifier tube 35, the anode of which is connected through a condenser 36 and volume control adjuster 37 with a terminal 38. A switch 39 is provided for the purpose of connecting either the terminal 33 or terminal 38 with a switch arm 40 which is mechanically coupled with a switch arm 41. The switch arms 40, 41 are adapted to be placed in contact either with terminals 42, 43 of a resonant and high-pass and low-pass filter 44 with a variable band width and position (as shown in Fig. 1) or with the terminals 45, 46 of a rejection filter 47 with a variable band width and position. The terminal 42 of the resonant filter 44 is adapted to be connected through the switch arm 41 and a lead 48 with a terminal 49. The rejection filter 47 is connected to the lead 48 and thence to the terminal 49 through a lead 50. As will be seen from the drawing, the terminal 49 is adapted to be connected through the switch arm 15 with the volume control 12^a.

The volume control 12^a is connected by a lead 51 to the primary 52 of a transformer of which the secondary 53 is arranged in the grid circuit of an amplifier 54, the anode circuit of which contains the primary 55 of a push-pull transformer 56. The secondary 57 of the transformer 56 is provided with a number of tapping points 58 for variation of the impedance and is also tapped at the start

point 59. By means of a switch 60 and lead 60^a, a terminal base 61 may be connected to any one of the tapping points 58. The start point 59 is in the grid circuit of an amplifying valve 62.

A volume level indicator has a rectifying valve 63, of which the plate or anode is connected through a stabilising resistance 64 and condenser 65 to the anode of the amplifying valve 62. The cathode of the rectifying valve 63 is connected by a lead 66 with a D.C. milli-ammeter or micro-ammeter 67 shunted by a condenser 68 and a variable resistance 68^a.

The contact base 61 is provided with a number of fixed contacts 69, 69^a, corresponding to the number of telephone or other receivers intended to be served by the apparatus. Each contact 69 or 69^a is adapted to co-operate with a switch arm 70 to 70^a as the case may be. The switch arm 70 or 70^a is connected by a lead 71 or 71^a to the input terminal 72 or 72^a.

In the drawing, the receivers are represented by headphones 73, 73^a. The means associated with each head-phone 73 or 73^a, and adapted to be connected up with the portions of the apparatus already described through the input terminal 72 or 72^a, are similar in the case of each head-phone and only such means as applies to the head-phone 73 will, for the sake of brevity, be described, reference numerals applied in the drawing to the parts of the one means corresponding to the numerals applied to the parts of the other means.

A resonant filter 74, which is both a band pass filter and a low and high rejection filter, is connected by the leads 75, 76 to terminals 77, 78. Ganged switch arms 79, 80, are adapted to contact with either the terminals 77, 78 or terminals 81, 82. These latter terminals are in circuit through leads 83, 84 with a band reject filter 85. The switch arm 79 is connected through a lead 86 with an attenuator 87, which in turn is in circuit with the head-phones 73 or other receiver.

The marking device whereby, in measuring hearing-loss, an audiogram is obtained, is illustrated in Fig. 2. This device comprises a drum 88 which is rotatably mounted on a shaft 89. This shaft is, in turn, rotatably mounted in a stand 90. A portion 91 of the shaft 89 is screw-threaded and is engaged by a nut 92 which is fixed by a stud 93 to the drum 88, so that as the shaft 89 revolves, the drum 88 is moved parallel to its axis.

The end 88^a of the drum 88 is formed with apertures 94. Driving pins 95 pass slidably through the apertures 94 and are fixed at one end to a worm wheel 96

in mesh with a worm 97. A paper or card-board chart 98 is adapted to be wrapped round the drum 88 and to be secured thereon by a detachable locking strip 99.

- 5 The chart is marked with vertical lines or ordinates 100 at intervals corresponding to a predetermined number of cycles per second (frequency), and is also marked with horizontal lines or abscissæ 101 at intervals representing a predetermined number of decibels (hearing-loss). A punch or marker 102 is mounted on a hammer or lever 103, of which the opposite end is pivotally connected to an armature or solenoid 20 which depends into an actuating coil 21 arranged in the stand 90. The shaft 89 is adapted to be operated by the frequency rotary relay 11 (Fig. 1). The worm 97 is operable by the volume rotary relay 14 (Fig. 1). The solenoid 20, 21 shown in Fig. 2 corresponds to the solenoid represented by the same numerals 20, 21 in Fig. 1 and, as indicated by this latter figure, is adapted to be energised either by depressing the key 23 or by the closing of the relay contacts 24.

The operation of the apparatus described is as follows:—

- 30 In order to carry out a test on a patient for hearing-loss, the patient puts on the head-phone 73. A tone of known frequency is then produced by means of the frequency generator 1, 2. The switch arm 15 is moved over so as to contact with the terminal 7 and the necessary volume correction is made by the adjuster 5 as indicated by volume level unit 67, 68 at output.
- 40 While maintaining the tone at the frequency chosen, the volume or intensity of the tone is gradually increased by means of the volume control 12^a. The frequency rotary relay 11 takes up a position corresponding to the setting of the frequency generator 1, 2, and the corresponding movement is transmitted through the shaft 89 (Fig. 2) to the nut 92 and drum 88, so as to move the chart 98 horizontally until the vertical line or ordinate 100 corresponding to the chosen frequency comes into line with the punch or marker 102. Similarly, the adjustment of the volume control 12^a and impulse transmitter 12^b (Fig. 1) causes a corresponding change to take place in the position of the volume rotary relay 14, which brings about a corresponding rotation of the worm 97, worm-wheel 96, arms 95 and drum 88, until the horizontal line or abscissa 101 of the chart 98 which corresponds to the setting of the volume control set 12^a and impulse transmitter 12^b (Fig. 1) comes into line with the punch or marker 102.

When the patient catches the first sound of the tone through the head-phone 73 (Fig. 1) he will close the key 23. This will cause the coil 21 of the solenoid 20 to be energised and the punch or marker 102 to be given a light upward blow or impression against the chart 98. The position marked by the punch or marker 102 on the chart 98 will correspond to the frequency in cycles per second of the tone and to the hearing-loss in decibels of the patient at this frequency. Independently of manual operation of the key 23 by the patient, the neuro-voltmeter 28 will record his nervous reaction on first hearing the tone at the head-phone 73 and will energise the relay coil 25 through the line 27 and control tube 26. The relay 25 will close the contacts 24, which in turn will cause the solenoid coil 21 to be energised and the punch 102 to mark the chart 98 at the exact point representing the hearing-loss at the instant the nervous reaction takes place. This marking of the chart 98 serves as a check on the marking obtained by the closing of the key 23 by the patient himself.

The accuracy of the marking of the chart 98 in respect of the hearing-loss is ensured by the volume level indicator constituted by the D.C. meter 67 condenser 68 and rectifying valve 63 with its stabilising resistance 64. The condenser 68 does not interfere with the response of the D.C. meter 67 to the rise of current but delays the return of the pointer or the meter on the fall of current. Thus, the meter 67 operates always as a maximum-reading ammeter and gives a true indication of the volume or intensity of tone as transmitted through the output side of the apparatus. Thus the operator is enabled to bring the volume level in the output side into agreement with the setting of the volume control 12^a at the input side of the apparatus by means of the adjusters 5, 32, 37. The D.C. meter 67 is calibrated so that, when the apparatus is perfectly balanced on its input and output sides, the reading of the D.C. meter will correspond to the setting of the volume control set 12^a, 12^b. The meter 67 should be of a high resistance and is conveniently a milli- or micro-ammeter. The capacity of the condenser 68 on the other hand should be made large. By means of this indicator, the average output over any required interval is indicated.

The procedure of plotting the levels of hearing-loss for different frequencies of tone is repeated for different settings of the frequency generator 1, 2, until, as indicated by the plotted points or markings (shown at 104 in Fig. 2), a complete

graph of the threshold of hearing for the patient is obtained on the chart 98. The chart is then removed from the drum 88 by detaching the marking strip 99 and can be used to enable the hearing-loss of the patient to be efficiently compensated.

For the purpose of compensating for hearing-loss with my apparatus (as distinct from measuring hearing-loss at particular frequencies), the volume control set 12^a, 12^b is placed in circuit with the microphone 29 or phonograph 34 by turning the switch arm 15 into contact with the terminal 49. If the microphone 29 is to be used, the switch arm 39 is turned into contact with the terminal 33, whereas if the phonograph 34 is to be used, the switch arm 39 is turned into contact with the terminal 38.

By means of the ganged switch arms 40, 41, either the band resonant high-pass and low-pass filter 44 or the band rejection filter 47 can be introduced into the circuit so as to strengthen or weaken any particular band of frequencies as may appear to be necessary, having regard to the nature of the complex voice, sound or music frequencies to be transmitted.

The volume of the complex frequencies generated by the microphone 29 or phonograph 34 as transmitted to the output side of the apparatus is controlled by the volume control set 12^a, and the reception at each individual head-phone 73, 73^a, can be regulated in respect of the rejection or resonating of selected frequencies by the filters 74, 85 and in respect of the intensity of tone by the attenuator 87. Separate filters 74, 85 and attenuators 87 are provided in conjunction with each receiver or head-phone, so that each patient or person can have the transmission suited to the particular characteristics of his or her own hearing-loss.

The apparatus enables an entire class, or the pupils of an entire institution, to be supplied with sound suited to the characteristics of hearing of each individual. Although only one apparatus is used, the provision of individual head-phones or receivers with appropriate rejection and resonant filters and attenuator, makes it possible, in the case of each person, to suppress sounds at which hearing is satisfactory, and to amplify other sounds, and balance up the whole so as to obtain a normal frequency response characteristic.

A further advantage of the invention is that no masking or substitution of scales in the volume control will be necessary for different forms of receiving devices e.g., a bone conductor as compared with an air-column conductor, it being possible

to adjust the output of energy to yield the acoustic pressure required for each particular form of conductor employed.

The apparatus is also capable of use for teaching the dumb to articulate and to speak (provided vocal chords are not paralysed) since the dumb person is enabled by means of the apparatus to hear the instructor's voice and the voices of fellow pupils or other persons.

Various modifications in the apparatus illustrated may be made without departing from the scope of the invention. For example, I may introduce in the lead 51 at the input side of the amplifier 52 a unit 105 containing band-pass, band-reject, low-pass, and high-pass filters variable over the entire audio range. Alternatively, I may use a corrector in the output side of the apparatus, comprising a constant impedance attenuator unit (introduced, e.g. in the lead 60^a—Fig. 1—between the amplifier and transformer and the receiving device). These units are calibrated so as to ensure that even when (in contrast to the case illustrated) there are no filters (such as 74, 85), or attenuators (87), in the individual receiving circuits, the filtering or modulation of the sounds to produce the desired frequency response characteristic best suited to the patient can nevertheless be effected. This form is particularly adapted to suit the needs of doctors, hospitals and clinics for testing separate individuals, as distinct from class or group instruction. As a further modification, I may provide, in addition to the amplifier above-mentioned, a sub-amplifier in which sound current passing through the amplifier can be collected and compensated according to the intensity of sound by means of a so-called "Compander", properly stabilised and designed to correct automatically the output energy to coincide with the position of the volume control set on the input side.

If desired, means may be provided for operating the frequency control set and volume control set automatically in accordance with the operation of the marking device (whether manually by the patient, or automatically by means of the neuro-voltmeter) when making the hearing-loss test. This means may comprise, firstly, an electric motor and control means whereby, when the first note is generated by the frequency generator, the said motor will be caused to operate the volume control set so as to increase the volume of the note step by step with a suitable period of duration of the note at each step, and, secondly, a further motor and control means whereby, on the

one hand, this motor will be caused to operate the frequency control set so as to step up the frequency of the note to the next predetermined value and whereby, on the other hand, the volume control set will be caused simultaneously to return to its first step and the first motor will be caused again to operate the volume control set so as to increase the volume of the note step by step as before, and so on for the other predetermined frequencies at which the hearing-loss is to be measured.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. An apparatus for measuring, or for measuring and compensating for, hearing-loss of the type stated, in which the plotting or marking of the levels of hearing-loss at selected frequencies is made directly on the chart or audiogram by a marking device, operable by means adapted to be actuated by a neuro-reaction meter, such as a neuro-voltmeter or lie-detector, applied to the patient, so that the marking device will be caused to perforate or mark the chart or audiogram automatically in accordance with variation in the nervous condition of the patient brought about by his first hearing the note transmitted to the telephone receiver, head-phones or receiving device.

2. An apparatus, as claimed in claim 1, in which the neuro-reaction meter is coupled to a high-gain amplifier whereby the minute currents produced in the meter by the nervous reaction of the patient are sufficiently amplified to enable a switch in the solenoid or equivalent circuit of the punch or marking member to be operated by a relay.

3. An apparatus, as claimed in claim 1 or 2, which comprises an input circuit having a variable frequency generator adapted to generate thermionic signals of individual frequencies, a microphone, phonograph, radio receiver or other means adapted to produce thermionic voice, music or other signals of complex frequencies, a volume control set, switch or like means for connecting said volume control set to either said generator or said microphone, phonograph or the like, means whereby the intensity or volume of the signals produced thereby may be varied, and an output circuit having one or more telephone receivers or other receiving devices, means for transmitting the aforesaid thermionic signal or signals to the one or more telephone receivers or devices, and a volume level indicator which comprises a rectifying valve and a

D.C. meter which is calibrated to suit the setting of the volume control set when the apparatus is perfectly balanced and which enables the signals passed to the one or more telephone receivers or devices always to agree with the setting of the volume control set in the input circuit in respect of their intensity or volume.

4. An apparatus, as claimed in claim 3, in which means for passing or rejecting selected frequency components transmitted to the one or more receiving devices, and/or attenuator means for controlling the intensity of the said components as fed to the said device or devices are or is provided in the output circuit, and/or in the individual receiving circuits.

5. An apparatus, as claimed in claim 1 or 2, comprising, in combination, an audio frequency generator, a variable frequency control for said generator, a variable volume control for said generator, telephonic receiving means, means whereby audio frequencies produced by said generator are transmitted to said receiving means, chart means, a device for marking directly on said chart means, levels of hearing-loss of said person in detecting selected frequencies at said receiving means, and relay means actuated by said volume and frequency controls for operating said marking device automatically in accordance with said frequency control and said volume control.

6. An apparatus, according to claim 5, comprising an electric motor, control means therefor whereby, when a note is generated by said frequency generator, said motor will be caused to operate said volume control so as to increase the volume of the note step by step with a suitable period of duration of the note at each step, a second electric motor, and control means therefor whereby said second motor will be caused to operate said frequency control so as to step up the frequency of the note to the next predetermined value and whereby said volume control will be caused simultaneously to return to its first step and said first motor will be caused again to operate said volume control so as to increase the volume of the note step by step as before, and so on for the other predetermined frequencies at which said hearing-loss is to be measured.

7. An apparatus for measuring, or for measuring and compensating for, hearing-loss of the type stated, arranged and adapted to operate substantially as described with reference to Fig. 1 of the accompanying drawings.

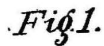
8. An apparatus for measuring, or for

measuring and compensating for, hearing-loss of the type stated, constructed, arranged and adapted to operate substantially as described and illustrated in Figs. 1 and 2 of the accompanying drawings.

Dated this 28th day of November, 1944.
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604.357 COMPLETE SPECIFICATION



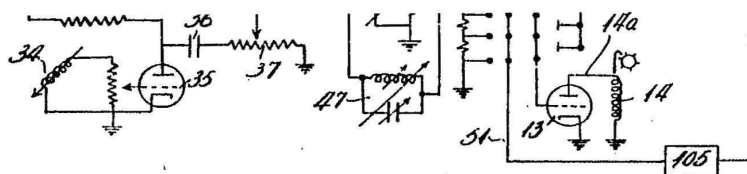


Fig. 1.

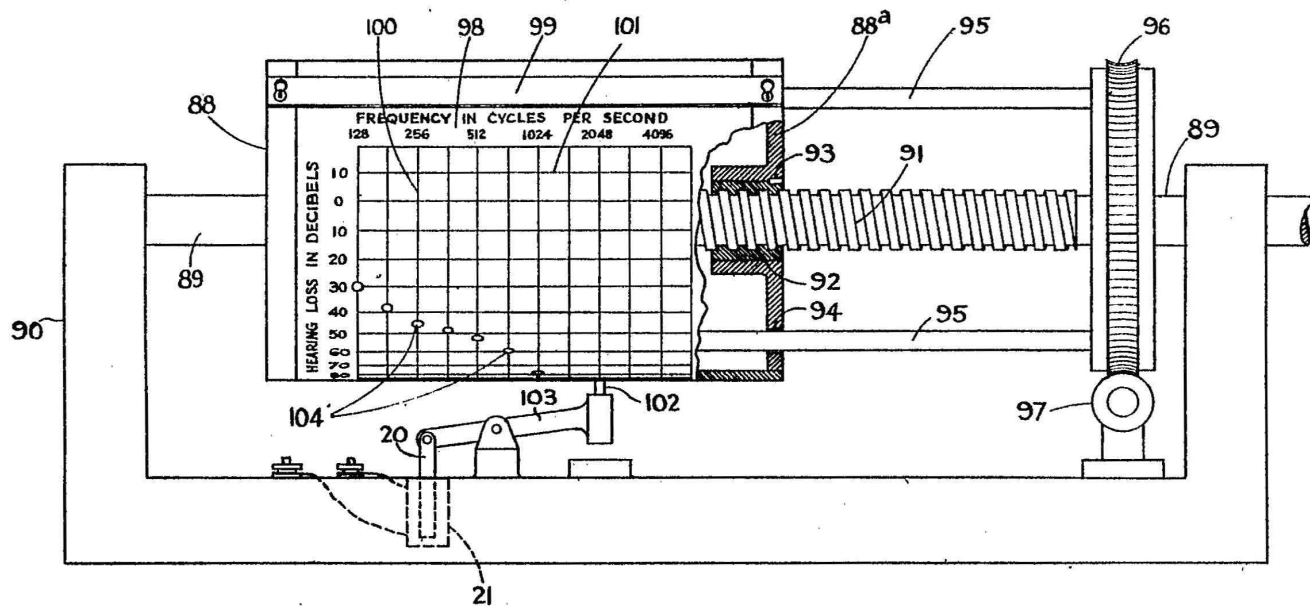
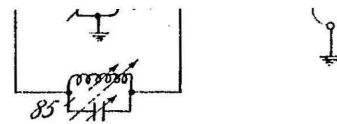


Fig. 2.

[This Drawing is a reproduction of the Original on a reduced scale.]

604,357 COMPLETE SPECIFICATION

SHEET 1

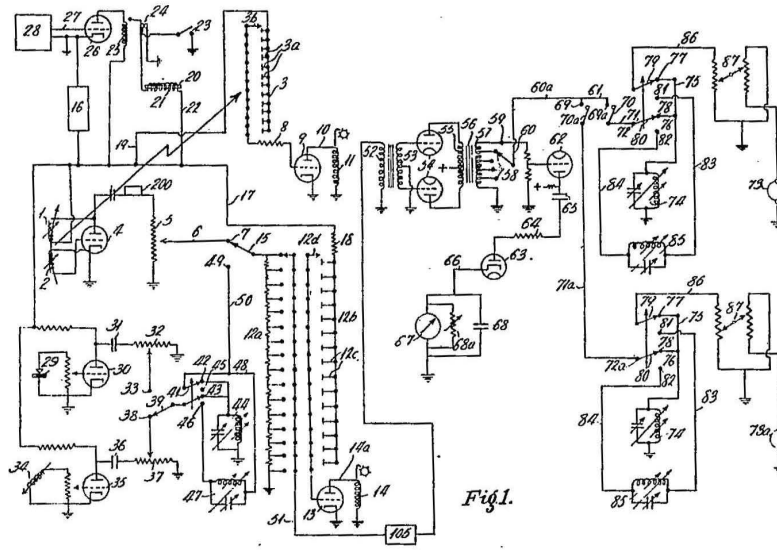


Fig. 1.

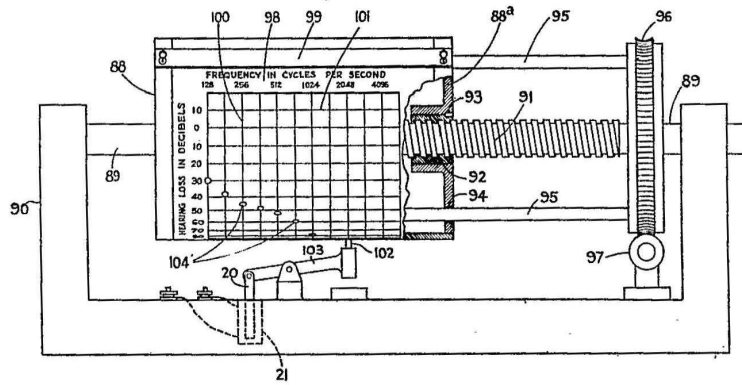


Fig. 2.

H.M.S.O. (P. 2)

2 SHEETS
SHEET 2