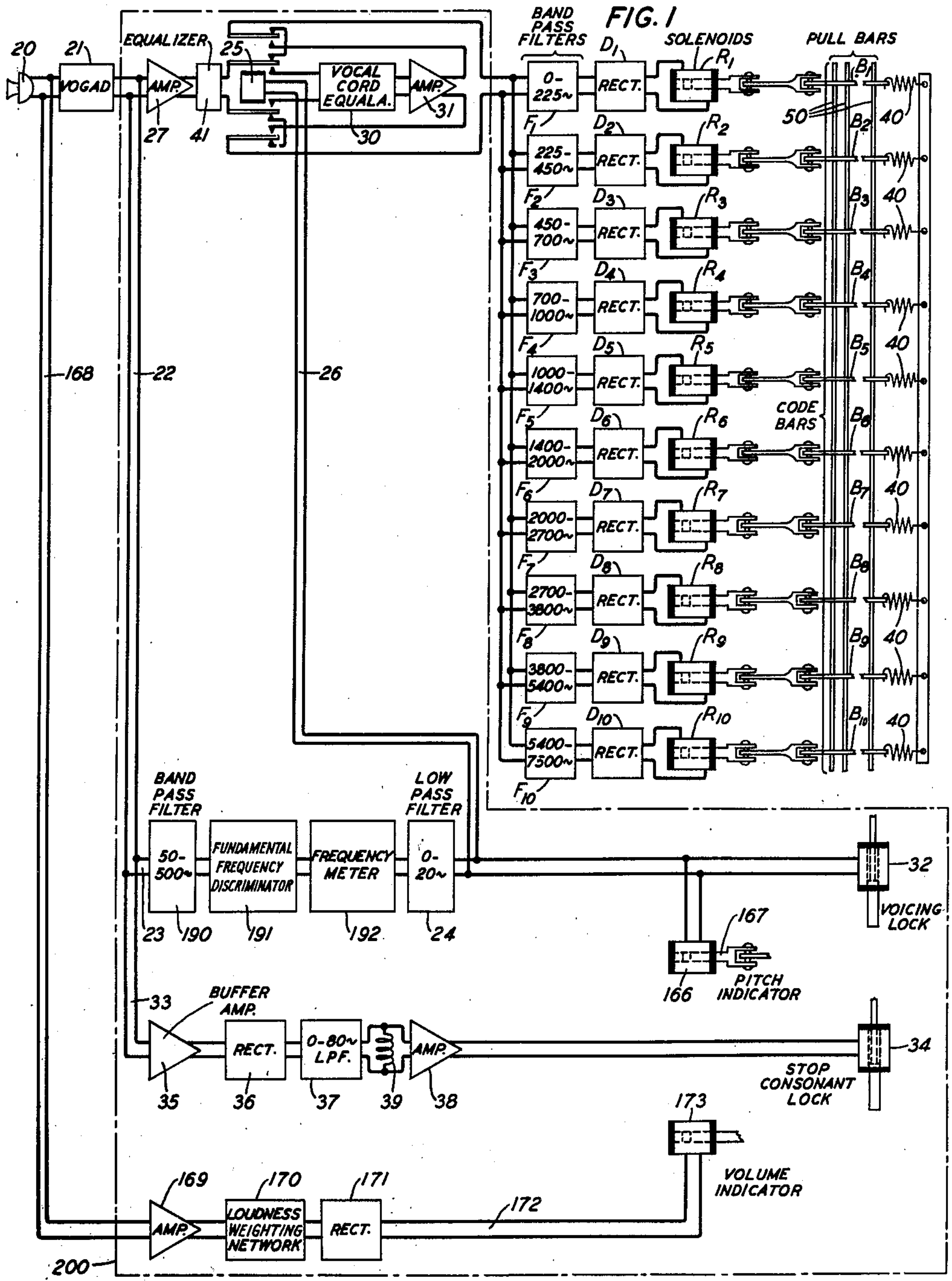
March 26, 1940. H. W. DUDLEY 2,195,081

SOUND PRINTING MECHANISM

Filed July 1, 1938 5 Sheets-Sheet 1



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SOUND PRINTING MECHANISM

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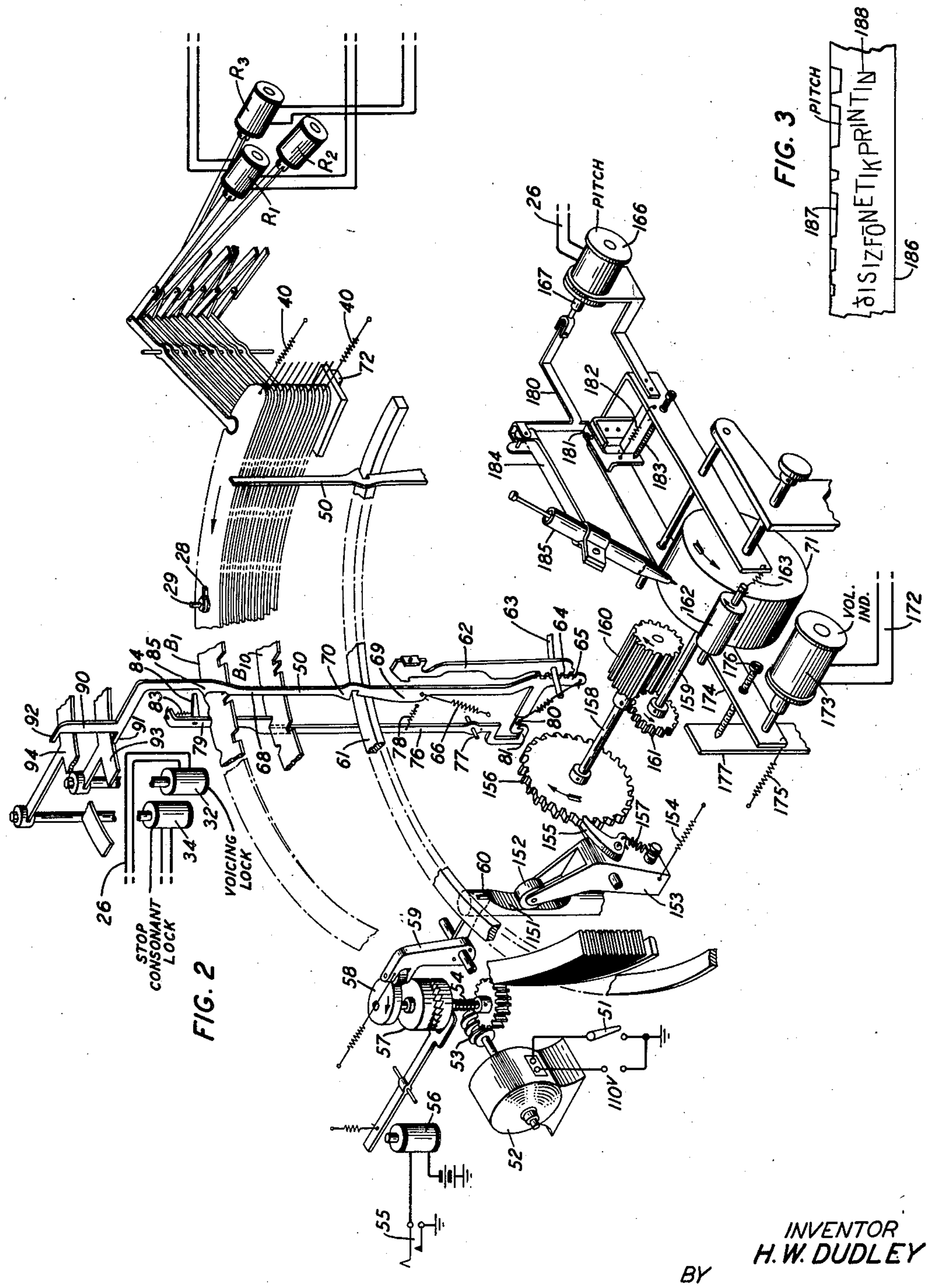

FIG. 2

FIG. 3

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FIG. 4

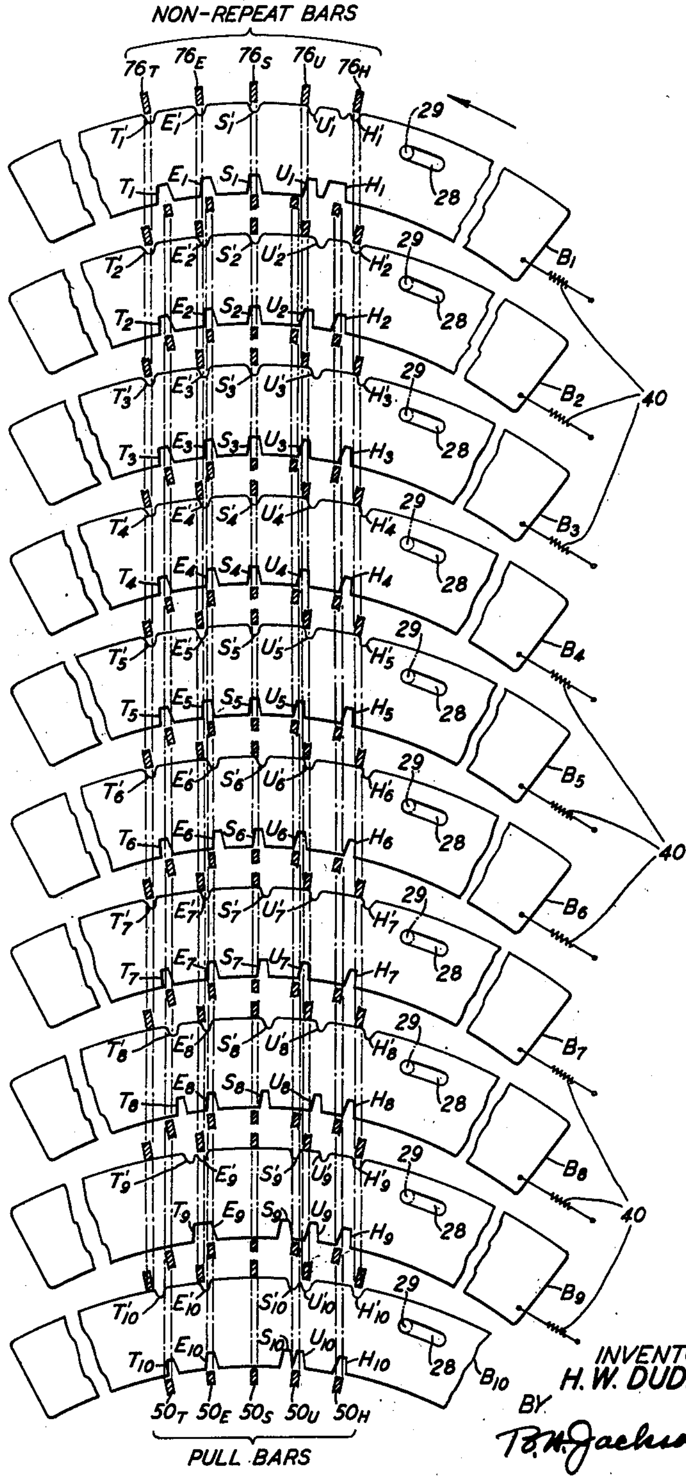

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FIG. 5

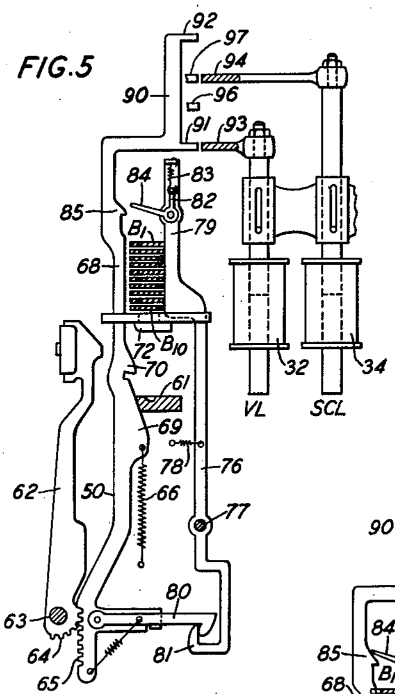

FIG. 6

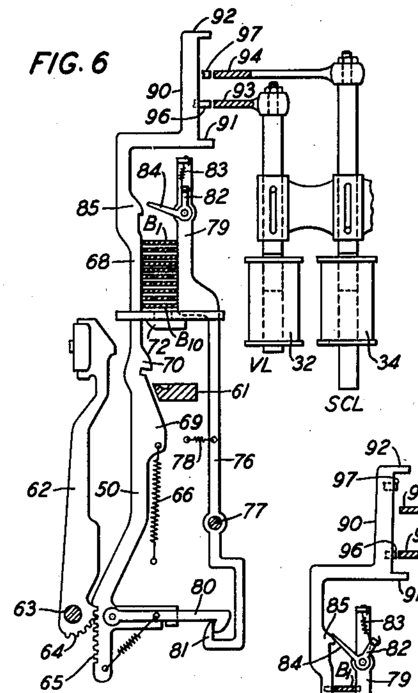

FIG. 7

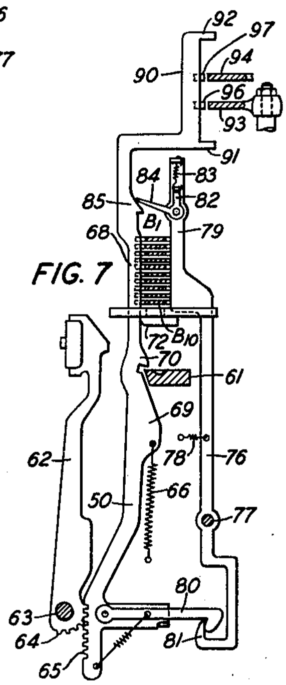

FIG. 8

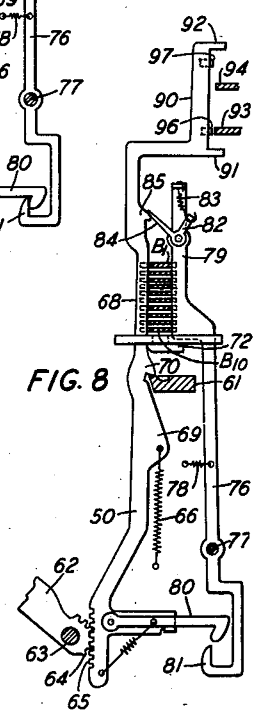

FIG. 9

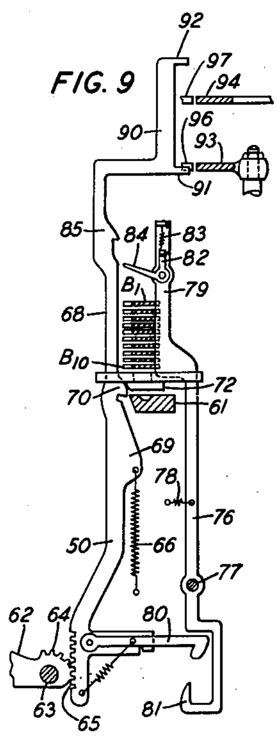

FIG. 10

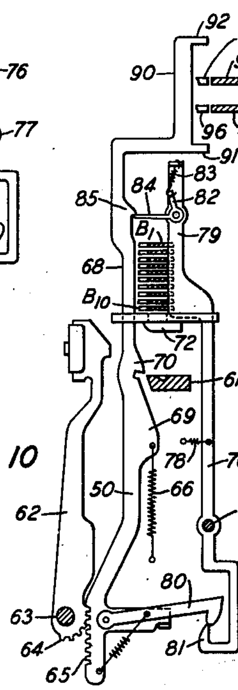

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FIG. 11A FIG. 11B FIG. 11C FIG. 11D

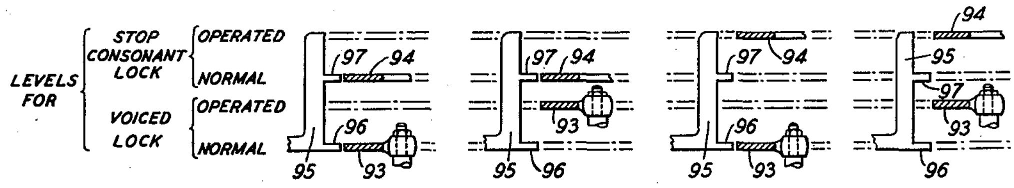


FIG. 12A FIG. 12B FIG. 12C FIG. 12D

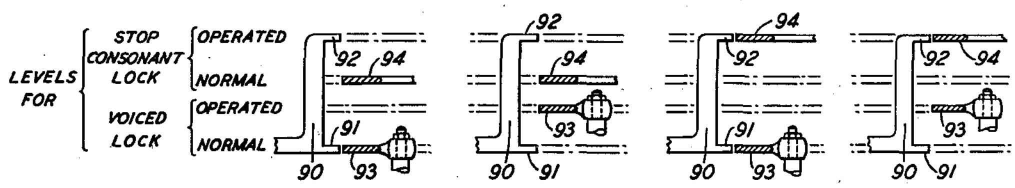


FIG. 13A FIG. 13B FIG. 13C FIG. 13D

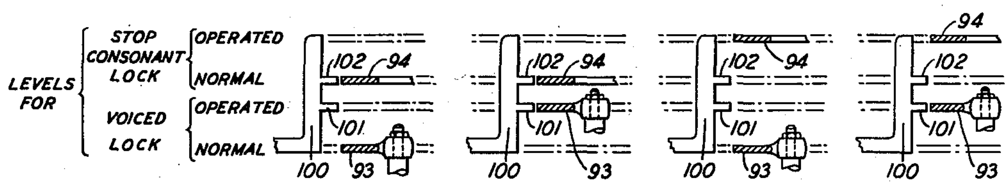
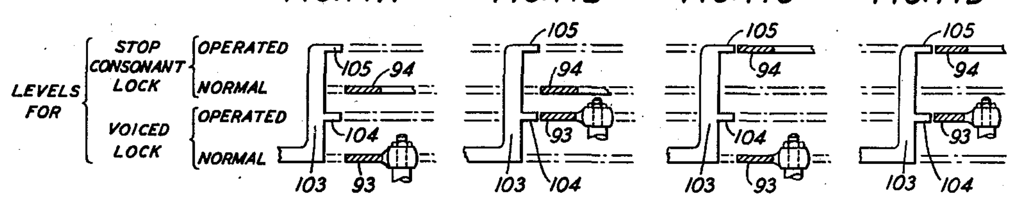


FIG. 14A FIG. 14B FIG. 14C FIG. 14D



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Patented Mar. 26, 1940 2,195,081

UNITED STATES PATENT OFFICE

2,195,081

SOUND PRINTING MECHANISM

Homer W. Dudley, Garden City, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application July 1, 1938, Serial No. 216,943

25 Claims. (Cl. 178—31)

This invention relates to sound printing mechanisms and has for an object the provision of means for translating spoken sounds into printed words.

In order that a suitable printing mechanism may be controlled to type characters from which the spoken sounds may be interpreted by the eye, it is necessary to analyze the sounds and derive therefrom a set of parameters which collectively define each sound and distinguish each sound of importance in speech from all other speech sounds. In choosing the set of parameters to be employed for this purpose use is made of the fact that one set of parameters can be substituted for another set without any loss of definition so long as the number of independent parameters remains unchanged.

As pointed out in my earlier U. S. patent application Serial No. 181,275, filed December 23, 1937, the number of movable or variable elements of the vocal system that are controlled as parameters to give the desired speech production and are movable or variable substantially independently of one another by the muscles of the vocal system is small. In other words, the number of variables or parameters that can be controlled substantially independently in speech production is small, being of the order of ten. Moreover, for each of the physical elements the minimum time it can go through a complete cycle of change in position is not less than about .1 second. Consequently, each independent variable has a fundamental frequency of not over 10 cycles per second while engaged in speech production.

Therefore, the speech defining signals into which the spoken message is translated for controlling the printing mechanism may be any signals derived from the message providing the derived signals give as many independent variable quantities or parameters as the number of independent variables involved in the production of speech. Furthermore, the chosen parameters need not be entirely independent provided their number be increased sufficiently to make up for their lack of independence. In accordance with the preferred form of this invention, the chosen parameters may be the average amounts of power present in selected subbands of the speech frequency range. For example, the speech frequency range by means of band-pass filters may be divided into ten subbands collectively extending over the frequency range of importance in speech and the average amount of power in each subband may be selectively utilized to cause the printing of symbols representing the message. The printed record will, of course, be phonetic in character as contrasted with the usual printed record which is non-phonetic.

The printing mechanism employed in this invention may comprise a plurality of slotted code bars each controlled in its movement by the average amount of power in one of the subbands into which the speech wave is divided so that each slotted bar is capable of assuming any one of several positions dependent upon the power level in its assigned subband for each spoken sound. It, therefore, follows that the slotted bars in response to a spoken sound will assume relative positions individual to that sound and means testing for the relative actuated positions of the slotted bars may be utilized to control the printing of a symbol indicative of that sound.

In accordance with a preferred embodiment of the sound printing mechanism of this invention the speech sounds are picked up by a microphone and transmitted to an amplifier whose gain is automatically adjusted for a constant speech level without, however, disturbing the relative loudness of the sounds making up a given word. The relatively constant volume output of this amplifier is next analyzed by a multiplicity of band-pass filters each passing a different subband of the speech frequency range and collectively passing the important frequency range of speech sound, for example, from 0 to 7500 cycles. The output of each filter then goes to a rectifier to produce a syllabic change in current proportional to the amount of energy in the particular frequency band passed by its filter. This syllabic changing energy from each rectifier energizes an electromagnet for actuating a selecting bar which may be similar in character to the code bars employed in teletypewriters. These selecting bars, therefore, have deflections varying with the amount of energy in the particular subbands. The selecting bars may have slots cut in them in such a manner that the speech currents for a given sound line up one set of slots in the bars so that a testing device for that particular sound can fall into the aligned slots. When a testing device enters the slots, an associated typing key may be actuated to type on a movable recording tape a symbol representing the given sound. Other features of the invention will appear from the detailed description hereinafter given.

Referring to the drawings,

Fig. 1 represents the electrical circuits of one form of this invention;

Fig. 2 represents printing mechanism which may be controlled by the electrical apparatus of Fig. 1;

Fig. 3 represents the type of record obtainable by the apparatus of Figs. 1 and 2;

Fig. 4 is a plan view of portions of the slotted bars utilized in the printing apparatus of Fig. 2;

Figs. 5 to 10, inclusive, represent the various stages in the operation of a given type bar and its associated mechanism when controlled by the apparatus of Figs. 1 and 2;

Figs. 11—A to 11—D, inclusive, illustrate in schematic form how a type bar bearing a symbol representing a voiced stop sound may be prevented from printing when the analyzed sound is of a different type;

Figs. 12—A to 12—D, inclusive, illustrate in schematic form how a type bar representing a voiced non-stop sound may be prevented from printing when the analyzed sound is of another type;

Figs. 13—A to 13—D, inclusive, illustrate in schematic form how a type bar bearing a symbol representing an unvoiced stop sound may be prevented from printing when the analyzed sound is of another type; and

Figs. 14—A to 14—D, inclusive, illustrate in schematic form how a type bar bearing a symbol representing an unvoiced non-stop sound may be prevented from printing when the analyzed sound is of another type.

Before discussing the character of the apparatus illustrated in the drawings, it is desirable to list the minimum number of symbols or characters which will be required to print phonetic speech. For the purpose of this specification, the speech sounds are divided into four groups, namely, voiced stop sounds, voiced non-stop sounds, unvoiced stop sounds and unvoiced non-stop sounds.

The voiced stop sounds of the first group are three in number and correspond to the three sounds which in the English language are designated by the letters B, D and G.

The voiced non-stop sounds of the second group comprise twenty-four sounds which may be divided into thirteen vowels, five semi-vowels, four voiced fricatives and two transitionals. The thirteen vowel sounds are given below by key words rather than by phonetic symbols, with the vowel sounds in boldface type:

see	fat	omit
fill	chaotic	tall
well	cool	father
ask	book	fur
		up.

The five semi-vowels included in the second group are the consonants shown in boldface type of the following words:

man lit ring.

The four voiced fricatives are the portions of the following words in boldface type:

zeal azure vat then.

The two transitionals included in the second group are the **w** sound in wile and the **y** sound in you.

The third group, namely, the unvoiced stop sounds, comprise three sounds represented in the English language by the three letters P, T and K.

The fourth group, namely, the unvoiced non-stop sounds comprises a total of six sounds including two unvoiced transitionals, the **h** sound in **h**ere, and the **wh** sound in **wh**at; and four unvoiced fricatives as indicated by the consonants which are in boldface type, in the following words:

seal ash fat thin.

This makes a minimum total of thirty-six phonetic symbols for recording speech sounds. Certain common sounds have been omitted from this list since they may be represented by symbols already given. Thus the **j** sound in **j**udge may be represented in print by two symbols, namely, by the symbol representing the **d** sound followed by the symbol representing the **z** sound in a**z**ure. The **ch** sound in **ch**urch would be represented by two symbols, namely, the symbol representing the **t** sound followed by the symbol representing the **sh** sound of **sh**e. Similarly, all the vowel diphthongs have been considered as the combinations of two vowel sounds.

It is, therefore, contemplated that a minimum number of thirty-six phonetic symbols will be needed in the printing mechanism to give intelligible printed phonetic speech, but, of course, this number may be considerably enlarged as desired to provide additional symbols representing still other sounds customarily found in the English language. The symbols employed on the type bars of the printing mechanism are preferably those of the alphabet of the International Phonetic Association as given, for example, in Webster's New International Dictionary, published in 1934, or as given in a book of Mulgrave entitled "Speech for the Classroom Teacher" published in New York in 1936 by Prentice-Hall, Incorporated.

Referring now to the circuit diaphragm of Fig. 1 the speech to be printed may be picked up by a microphone **20**. In order to compensate for variations in the volume of the received sounds so that the analyzed speech currents will always be the equivalent of those produced by a person talking with substantially the same degree of loudness and to compensate for any intermediate telephone line between the point of speech pick-up and the point of speech printing, the speech currents received from microphone **20** are impressed upon an amplifier **21** of the type called a vogad in the communication art, and shown in detail, for example, in British Patent 381,831. That is, amplifier **21** has its gain automatically controlled by slow variations in the level of the received currents but with its gain unchanged by syllabic variations in the received volume whereby the output of amplifier **21** gives the speech currents for each word at substantially the same level. In addition to the vogad or as a substitute for it, an instantaneous speech control such as a compressor or expandor may be found useful in some cases, the former to reduce the operating range needed for adequate speech analysis, the latter to reduce the effect of noise. A particular circuit for the compressor is given in Crisson U. S. Patent No. 1,737,830 of December 3, 1929, and for the expandor is given in the Mathes U. S. Patent 1,757,729 of May 6, 1930. At this point in the circuit of Fig. 1 it is important to distinguish between currents representing voiced sounds and unvoiced sounds and, therefore, a portion of the output of vogad **21** by leads **22** is impressed upon a fundamental frequency discriminating circuit **23** of such a character that the output current from low-pass filter **24** will be substantially zero for all unvoiced sounds but for voiced sounds will have an amplitude proportional to the pitch of the fundamental frequency. Hence, relay **25** which by leads **26** is connected to the output of filter **24** will be non-operated by unvoiced sounds but will be operated by all voiced sounds.

Therefore, for unvoiced sounds the output from the additional amplifier **27** because of the non-operation of relay **25** will be impressed directly upon ten band-pass filters F_1 to F_{10} all connected in parallel to the output of amplifier **27**. These band-pass filters collectively pass the frequency range of importance in speech, say, from 0 to 7500 cycles, with filter F_1 passing the band from 0 to 225 cycles per second; filter F_2 passing the band from 225 to 450 cycles per second; filter F_3 passing the band from 450 to 700 cycles per second; filter F_4 passing the band from 700 to 1000 cycles per second; filter F_5 passing the band from 1000 to 1400 cycles per second; filter F_6 passing the band from 1400 to 2000 cycles per second; filter F_7 passing the band from 2000 to 2700 cycles per second; filter F_8 passing the band from 2700 to 3800 cycles per second; filter F_9 passing the band from 3800 to 5400 cycles per second; and filter F_{10} passing the band from 5400 to 7500 cycles per second. The output from each of the band-pass filters F_1 to F_{10} is rectified by one of the rectifiers D_1 to D_{10} and the rectified current from each subband is impressed upon one of the electromagnets R_1 to R_{10}. Therefore, each electromagnet R_1 to R_{10} attracts its armature with a force determined by the average energy level of that portion of the speech wave transmitted by its associated filter so that electromagnet R_1 attracts its armature with a pull determined by the average energy level in the frequency range from 0 to 225 cycles per second, electromagnet R_2 attracts its armature with a pull determined by the average energy level in the frequency range from 225 to 450 cycles per second, etc.

The armature of each of the electromagnets R_1 to R_{10} is suitably coupled by a multiplying lever to one of the arcuate-shaped code bars B_1 to B_{10} shown more clearly in Fig. 2. Each code bar B_1 to B_{10} is biased by means of one of the springs **40** to a normal position whereby the left end of a slot **28** in each code bar lies against a stop pin **29**. Hence, each of the code bars B_1 to B_{10} by means of its associated electromagnet will be moved from its normal position an amount controlled at each instant by the average energy level in the speech frequency subband passed by the filter associated with each electromagnet. We may assume, for example, for the complex electrical wave representing a certain unvoiced sound such as s in sin that there is no appreciable energy lying in the frequency band between 0 and 1400 cycles per second, and hence for such a wave code bars B_1 to B_5, inclusive, will remain in their normal positions; that there is a small amount of energy in the band from 1400 to 2000 cycles per second, and hence code bar B_6 will be moved a small amount; that there is a somewhat greater amount of energy in the band from 2000 to 2700 cycles per second so that code bar B_7 will be moved a greater distance than code bar B_6; that there is slightly more energy in the band from 2700 to 3800 cycles per second so that code bar B_8 will be moved a greater distance than code bar B_7; that the amount of energy in the band from 3800 to 5400 cycles per second is substantially greater than in the band from 2700 to 3800 cycles per second so that code bar B_9 will be moved considerably more than code bar B_8; and that there is substantially the same amount of energy in the band from 5400 to 7500 cycles per second so that code bar B_{10} will be moved the same amount as B_9. With the code bars occupying the positions just recited, they are in such positions that when they are tested by the printing mechanism the code bars will permit the printing of the symbol representing the s sound in sin but will not permit the printing of any other symbol. The manner in which the testing of the code bars and the printing is done will be described later.

The above description has traced the operation of the code bars in response to an unvoiced sound. Their operation for a voiced sound is quite similar except that for a voiced sound relay **25** will be operated so that the output of amplifier **27** instead of being impressed directly upon the band-pass filters will be transmitted through an equalizing network **30** and another amplifier **31** before reaching the filters. Equalizer **30** is designed to correct the natural falling off of the upper harmonics with frequency in the case of sounds produced by the vocal cords and to make the amplitude of the fundamental and all its harmonics more nearly uniform as is the case with unvoiced sounds. The amount of equalization needed can be obtained from Fig. 2 of my above-mentioned application Serial No. 181,275 from which it is apparent that the required equalization varies from a loss of 30 decibels at 100 cycles per second to zero at 3000 cycles per second; and that for frequencies above 3000 cycles per second a gain is needed for the equalizer instead of a loss. However, such a gain would lead to increasing the line noise by amplification, so from 3000 cycles to the upper end of the speech band it is more desirable to have zero loss and such a condition may be assumed for the circuits of Fig. 1 herein. This equalization produced by network **30** makes each subband of the speech frequency range equally useful in determining what voiced symbols shall be printed as otherwise significant amounts of energy in certain of the upper subbands might be at such a small energy level compared to the fundamental that the code bar for such an upper subband might be left in normal position and cause false printing. Equalizer **30**, therefore, reduces the amplitude of the fundamental and the major harmonics to a level more nearly equal to the higher harmonics and then amplifier **31** is employed to raise the level of the fundamental and its harmonics to the level desired to secure the selective operation of the code bars.

It may be found helpful to insert an equalizer **41** after amplifier **27** to correct for the increasing amounts of energy in the upper bands as compared with the lower bands passed by filters F_1 to F_{10} due to the increasing width of the passed band as one proceeds from filter F_2 to filter F_{10}; for example, filters F_1 and F_2 pass bands 225 cycles in width while filter F_{10} passes a band 2100 cycles wide. This correction produced by equalizer **41** may amount to a loss of 1 decibel per channel starting with the channel containing filter F_2.

As additional aids in preventing false printing, applicant in the preferred embodiment of the invention employs a so-called voicing lock which must be operated before a symbol for a voiced sound may be printed and also employs a stop consonant lock which must be operated before a symbol for a stop consonant may be printed. The voicing lock comprises an electromagnet **32** connected to the output of filter **24** and as previously described the output current of filter **24** is substantially zero for unvoiced sounds while its output is of substantial amplitude for all voiced sounds. Hence, electromagnet **32** will be energized only for voiced sounds.

Connected across the output of vogad **21** in parallel with channel **23** is another channel **33** leading to an electromagnet **34** constituting a part of the stop consonant lock of the printing mechanism. Channel **33** includes an amplifier **35** to isolate channel **33** from the other circuits connected across the output terminals of vogad **21**. The output of amplifier **35** is rectified by rectifier **36** and then impressed on the low-pass filter **37** which passes the band between 0 and 80 cycles to eliminate the fundamental frequency of any voiced sound and the conductors between filter **37** and the input of low frequency amplifier **38** are shunted by a large inductance **39** with electromagnet **34** responsive to the output of amplifier **38**. When a sudden change in the energy level such as caused by a stop consonant sound is received by channel **33** a sudden pulse of energy goes through circuit **33** and builds up a potential across inductance **39** which being amplified by amplifier **38** will cause electromagnet **34** to operate. However, the sustained average energy level of a voiced sound will not produce sufficient potential across inductance **39** to cause the operation of electromagnet **34**. The manner in which electromagnets **32** and **34** control the printing operation will be described later.

Referring now to Fig. 2 it will be seen that the code bars B_1 to B_{10} are arcuate-shaped and mounted one above the other in a suitable manner to enable each code bar to move along an arcuate path when its associated electromagnet R_1 to R_{10} is energized, each code bar being biased by a spring **40** to a normal position with the left end of slot **28** against stop pin **29**, and the maximum movement of any code bar determined by the length of slot **28**.

These code bars B_1 to B_{10} and certain parts of the associated apparatus are somewhat similar to teletypewriter apparatus as disclosed in Lang et al. U. S. Patent 2,106,805, issued February 1, 1938, or Morton et al. U. S. Patent 1,745,633, issued February 4, 1930, except that the code bars of a teletypewriter are fewer in number and occupy only two possible positions, an operate position and a non-operate position, while each code bar B_1 to B_{10} is designed to be advanced over a wide range of positions including not only its normal position and its maximum position but also any intermediate position. That is, in order to print a given symbol it may be necessary that one code bar be moved .3 of the distance between its normal position and maximum position, another code bar .4 of that distance, another code bar .7 of that distance, another code bar to maximum position, etc. The arrangements of the slots in the code bars B_1 to B_{10} will be described later.

In order to render the printing mechanism of Fig. 2 effective, switch **51** should first be closed to connect a suitable power supply to motor **52** to rotate gear **53** which in turn rotates the drive shaft **54**. Switch **55** may then be closed to operate relay **56**, thereby bringing into contact the parts of clutch **57**. This rotates cam **58** which forces lever **59** back and forth thereby causing the main bail plunger **60** to move up and down and cause the main bail **61** to execute a similar upward and downward movement. Each upward movement of main bail **61** causes all pull bars **50** to test the setting of the code bars B_1 to B_{10}, there being a pull bar **50** for each character to be printed although for simplification purposes only one pull bar is completely shown on the drawings.

As shown more clearly in Fig. 5 each type bar **62** is suitably supported for rotative movement about an axis defined by a stationary pin **63**. The lower end of each type bar forms a segmental gear **64** which meshes with a toothed rack **65** forming the lower end of each pull bar **50**, suitable means, not shown, being provided for holding gear segment **64** in engagement with rack **65**, while permitting a slight pivotal movement of the associated pull bar **50**. Each pull bar **50** above rack **65** extends first slightly outwardly and then upwardly and a spring **66** tends to move the pull bar downwardly and rearwardly and hold the pull bar and its associated type bar in normal position as shown in Fig. 5 with the pull bar pressed against the forward edge of the main bail **61** when the main bail is in its normal position. It will also be noted from Fig. 5 that with the pull bars in normal position an intermediate portion **68** of each pull bar lies in front of but is spaced slightly from the notched inner edges of the code bars B_1 to B_{10}.

Main bail **61** as previously described is continually being raised and lowered by plunger **60**. As bail **61** starts to move upwardly as in Fig. 6 this upward movement due to cam surface **69** on each pull bar enables springs **66** to move all pull bars **50** rearwardly against the notched front edges of the code bars B_1 to B_{10} as shown in Fig. 6. It may be assumed that electromagnets R_1 to R_{10} have moved code bars B_1 to B_{10} to such positions as to permit one of the pull bars **50** to drop into the slots (see Fig. 7) far enough to bring a rearwardly projecting lug **70** into the path of movement of the main bail **61**. Upon the continued upward movement of main bail **61** its forward edge engages lug **70** of the selected pull bar and moves the selected pull bar upwardly (see Fig. 8) thereby throwing the associated type bar **62** to the printing point, thereby printing a symbol on a strip of paper supported by platen **71**. The latter part of the upward movement of the selected pull bar causes lug **70** to engage a stationary cam **72** which throws the selected pull bar forwardly and out of the notches in the code bars as shown in Fig. 9 whereby the code bars may be reactuated for another alignment to provide for the later selection of another pull bar. Spring **66** thereupon lowers the selected pull bar and raises its associated type bar to substantially their normal positions as shown in Fig. 10 in which the bail bar **61** is shown as returned to its starting position.

Inasmuch as it is contemplated that occasionally the frequency of movement of the main bail **61** may cause its next upward excursion before the code bars have been moved from the alignment which permitted the actuation of a type bar by its previous excursion, the preferred form of the invention provides a repetition lock whereby after one pull bar has entered the slots in the code bars the said one pull bar cannot reenter the slots until there has been a realignment of at least one of the code bars. Associated with each pull bar **50** is a non-repeat lock bar **76** pivoted on a stationary pin **77**. The upper portion **79** of bar **76** is biased towards the rear edges of the code bars due to biasing springs **78**. The rear edges of the code bars B_1 to B_{10} are also provided with shallow slots as will be described later so arranged that when the code bars occupy positions to enable a selected pull bar to enter slots in the front edges of the code bars all the code bars will have aligned slots in their rear edges to permit the entrance of the non-repeat bar associated with the particular pull bar. However, as long as each pull bar **50** is in its normal position as in Fig. 5 the associated non-repeat bar **76** is prevented from entering any slots in the code bars since there is pivoted to the lower end of each pull bar **50** a spring latch **80** engaging a hook **81** on the lower end of the non-repeat bar **76**.

As soon as any pull bar **50** after entering the aligned slots in the front edges of the code bars has been pulled upwardly due to the main bail **61** engaging lug **70** (Fig. 8) the latch **80** is lifted free of hook **81** and spring **78** then causes the associated non-repeat bar to enter the aligned slots in the rear edges of the code bars. Pivoted to the upper end of each non-repeat bar **76** is an angular lever **82** biased by spring **83** to the position shown in Fig. 5 with its arm **84** extending towards but not contacting with the associated pull bar **50** as long as the pull bar and the non-repeat bar are in their normal positions of Fig. 5. When the initial movement of the main bail **61** has permitted a pull bar to enter the aligned slots in the code bars this rearward movement of such a pull bar allows arm **84** to ride on the upper surface of lug **85** as shown in Fig. 7. When any pull bar **50** is lifted upwardly to cause a printing operation (Figs. 8 and 9) lug **85** passes above arm **84** and since the associated non-repeat bar **76** is now allowed to enter the aligned slots in the rear edges of the code bars the subsequent lowering of the pull bar **50** after the printing operation as in Fig. 10 causes arm **84** to be caught by lug **85** as long as the non-repeat bar **76** lies in the slots on the code bars. Arm **84**, therefore, prevents the pull bar **50** from entering the slots in the front edges of the code bars a second time as long as its associated non-repeat bar **76** is lying in the aligned slots in the rear edges of the code bars. It will also be noted from Fig. 10 that with the pull bar **50** retracted after a printing operation and with the associated non-repeat bar **76** lying in the slots in the code bars the spring latch **80** rests on the tip of hook **81**.

However, as soon as any one of the code bars B_1 to B_{10} is moved to a new position by the energization or deenergization of one of the electromagnets R_1 to R_{10}, such a movement of a code bar will force the non-repeat bar **76** rearwardly out of the slots in the code bars, thereby freeing arm **84** from lug **85** and moving the lower hooked end of the non-repeat bar **76** inwardly to enable latch **80** to engage hook **81** to thereafter hold the non-repeat bar out of engagement with the code bars until after the cycle of operation is begun again involving the selection of the pull bar **50** illustrated in Figs. 5 to 10. That is, the apparatus of Fig. 10 will be restored to their normal positions of Fig. 5 as soon as one of the code bars B_1 to B_{10} has been moved to force the non-repeat bar out of the slots in the code bars.

Applicant's preferred embodiment also includes means for preventing false printing by dividing the possible speech sounds into groups and at any one time preventing the printing of all symbols except those representing the sounds of one group. Thus, the printing mechanism may be arranged to determine whether or not a particular setting of the code bars is due to a voiced or an unvoiced sound and if it is due to a voiced sound to automatically lock all pull bars which are associated with type bars representing unvoiced sounds.

In the previous description the speech sounds to be printed by appropriate symbols were divided into four groups, namely, voiced or unvoiced stop sounds and voiced or unvoiced non-stop sounds. The apparatus of Figs. 1 to 10 include means for distinguishing each group from the other three groups and for unlocking the type bars for the particular group to which each sound belongs.

Each pull bar **50** for the twenty-four voiced non-stop sounds previously listed is of the type disclosed in Figs. 5 to 10 with an upper extension **90** comprising two spaced lugs **91** and **92**. The armature of electromagnet **32** (Fig. 2) has an arcuate-shaped arm **93** which is adjacent to and aligned with the lugs **91** of all pull bars for the voiced non-stop sounds when the pull bars are in normal position and when electromagnet **32** is deenergized. It, therefore, follows that no symbol representing a voiced non-stop sound can be printed as long as electromagnet **32** is deenergized since as is apparent from Fig. 5 arm **93** will prevent any pull bar for a voiced non-stop sound from testing the code bars. However, when a voiced non-stop sound is received by microphone **20** and while the code bars in response to that sound are being set by electromagnets R_1 to R_{10}, electromagnet **32** will also be energized to raise arm **93** to a higher level (Figs. 6 to 10) out of the path of lug **91** when the movement of main bail **61** permits springs **66** to pull all of the pull bars inwardly to test the code bars. The position of arm **93** when electromagnet **32** is energized also serves to lock the pull bars for another group of sounds as will be described later. The type of control exercised by electromagnet **34** is similar to electromagnet **32** except that as long as electromagnet **34** is deenergized no symbol can be printed corresponding to a stop sound.

In explaining the printing control exercised by electromagnets **32** and **34** by reference to Figs. 11 to 14, inclusive, it should be noted from Fig. 1 that electromagnet **32** will be operated by all voiced non-stop sounds and all voiced stop sounds and will remain unoperated for all unvoiced stop or non-stop sounds; and that electromagnet **34** will be operated by all voiced and unvoiced stop sounds and will remain unoperated for all voiced and unvoiced non-stop sounds.

The upper portion of a pull bar for one of the twenty-four voiced non-stop sounds is shown in Figs. 12—A to 12—D where the pull bar has a lug **91** opposite arm **93** for the non-operated position of the armature of the voicing lock electromagnet **32** and has a lug **92** opposite the operated position of the corresponding arcuate arm **94** connected to the armature of the stop consonant lock electromagnet **34**. In Fig. 12—A both electromagnets **32** and **34** are non-operated with arm **93** lying in the path of lug **91** to prevent a printing operation by any pull bar for a voiced non-stop sound. In Fig. 12—B the arm **94** of the stop consonant lock is in normal position but arm **93** of the voice lock is in its operated position out of the path of lug **91** so that the condition of the controls shown in Fig. 12—B will permit the printing of any desired voiced non-stop sound. In Fig. 12—C the voiced lock arm **93** is normal and the stop consonant lock arm **94** is in its operated position from which it is obvious that pull bar **90** cannot be actuated to cause a printing operation. In Fig. 12—D the voiced lock arm **93** is in its operated position and the stop consonant lock arm **94** is in its operated condition from which it is obvious that the pull bar **90** cannot cause a printing operation due to the fact that arm **94** lies in the path of lug **92**. Therefore, as shown in Fig. 12—B the biasing arm **93** must be in its operated position and the stop consonant lock arm **94** must be in its normal position in order to secure the printing of any character representing one of the twenty-four voiced non-stop sounds.

The three pull bars representing the three voiced stop sounds may have their upper extensions of the type shown in Figs. 11—A to 11—D where the upper portion **95** of the pull bar has a lug **96** opposite the normal position of the voiced lock arm **93** and has a lug **97** opposite the normal position of the stop consonant lock arm **94**. An examination of the Figs. 11—A to 11—D will show that the printing corresponding to one of the voiced stop consonants can be secured only when both arms **93** and **94** are in their operated positions as shown in Fig. 11—D. When arms **93** and **94** are in their normal positions as shown in Fig. 11—A no printing operation can be made because arm **93** lies in the path of lug **96** and arm **94** lies in the path of lug **97**. When arm **93** is in its operated position and arm **94** is in its normal position it is apparent from Fig. 11—B that there can be no printing operation since arm **94** lies in the path of lug **97**. When arm **93** is in its normal position and arm **94** is in its operated position it is apparent from Fig. 11—C that no printing operation can be effected since arm **93** lies in the path of lug **96**.

The upper portion of a pull bar for one of the three unvoiced stop consonant sounds may be of the type shown in Figs. 13—A to 13—D where the upper extension **100** of the pull bar has a lug **101** opposite the operated position of arm **93** and a lug **102** opposite the normal position of arm **94**. It will be apparent that the printing of a symbol representing one of the unvoiced stop sounds will be permitted when the voiced lock arm **93** is normal and when the stop consonant lock arm **94** is in its operated position, as shown in Fig. 13—C. When both arms **93** and **94** are in their normal positions it will be apparent from Fig. 13—A that no printing operation will be permitted since arm **94** lies in the path of lug **102**. When arm **93** is in its operated position and arm **94** is in its normal position it will be apparent from Fig. 13—B that no printing operation will be permitted since arm **93** lies in the path of lug **101** and arm **94** lies in the path of lug **102**. When arms **93** and **94** are both in their operated positions it will be apparent from Fig. 13—D that no printing operation will be permitted since arm **93** lies in the path of lug **101**.

The pull bars for the six unvoiced non-stop sounds may each have an upper extension **103** as shown in Figs. 14—A to 14—D, the said extension **103** having a lug **104** opposite the operated position of arm **93** and a lug **105** opposite the operated position of arm **94**. It will be apparent from Fig. 14—A that the printing of an unvoiced non-stop sound will be permitted when both arms **93** and **94** are in their normal positions where they lie out of the path of lugs **104**, **105**. When the arm **93** is in its operated position and arm **94** is in its normal position it will be apparent from Fig. 14—B that no printing operation will be permitted since arm **93** lies in the path of lug **104**. When arm **93** is in its normal position and arm **94** is in its operated position it will be apparent from Fig. 14—C that no printing operation will be permitted since arm **94** lies in the path of lug **105**. When arms **93** and **94** are both in their operated positions it will be apparent from Fig. 14—D that no printing operation will be permitted since arm **93** lies in the path of lug **104** and arm **94** lies in the path of lug **105**.

As a summary of the above description it will be apparent that a voiced stop sound may be printed only when both electromagnets **32** and **34** are energized (Fig. 11—D); that a voiced non-stop sound can be printed only when electromagnet **32** is energized and electromagnet **34** deenergized (Fig. 12—B); that an unvoiced stop sound can be printed only when the electromagnet **32** is deenergized and electromagnet **34** energized (Fig. 13—C); and that an unvoiced non-stop sound can be printed only when both electromagnets **32** and **34** are deenergized (Fig. 14—A).

Various methods may be employed in determining the positions of the slots in the code bars B_1 to B_{10} in order that for a particular sound the code bars will be moved to align their slots for that sound to permit the printing of the appropriate symbol. Probably the most direct way to obtain this information is to determine the average energy level in each subband for each phonetic sound by connecting a recording oscillograph to the output of each of the rectifiers D_1 to D_{10} so as to measure the output current from each rectifier for each phonetic sound spoken into the microphone **20**, it being understood that for the measurement of voiced sounds equalizer **30** is included in the circuit to make all harmonics of the fundamental frequency of substantially the same amplitude as the fundamental. With the said equalizer **30** effective for voiced but not unvoiced sounds the energy distribution with frequency of thirty-two of the thirty-six sounds above listed, are given in the curves of Figs. 3 to 31 of my copending U. S. patent application Serial No. 181,275, filed December 23, 1937, where for each curve the loss in decibels is plotted against the frequency. By dividing each of these curves into the frequency subbands indicated on filters F_1 to F_{10} of Fig. 1 and integrating the portion of each curve representing each subband the relative amplitude of the output from each rectifier D_1 to D_{10} for each phonetic sound may be readily ascertained. It may be further assumed that electromagnets R_1 to R_{10} are similar and with springs **40** similar, and that the attractive force exerted by each of these electromagnets on its armature is a linear function of the amplitude of the current received from the associated rectifier. Hence, it may be assumed for the apparatus of Figs. 1 and 2 that the movement of each code bar B_1 to B_{10} from its normal position will be a linear function of the amplitude of the output current of its associated rectifier D_1 to D_{10}. However, any other arrangement found desirable may be used. For instance, the displacements may be made on a logarithmic basis instead of a linear one. This would be accomplished by a proper design of the magnetic parts of the electromagnets.

For illustrative purposes the code bars B_1 to B_{10} in Fig. 4 instead of being stacked one upon the other are all shown lying in a common plane so that the relative positions of their slots for certain sounds may be readily ascertained. Only a small portion of each code bar is shown in Fig. 4 and although it is assumed that the printing apparatus of Fig. 2 includes thirty-six pull bars, the disclosure in Fig. 4 includes only five pull bars since it is believed that these five pull bars will be sufficiently illustrative of the manner of operation of the code bars for all of the thirty-six pull bars contemplated by this invention. In Fig. 4 pull bar **50**$_H$ and associated non-repeat bar **76**$_H$ control the type bar for the **h** sound in **here**; the pull bar **50**$_U$ and associated non-repeat bar **76**$_U$ control the type bar for the boldfaced sound in the word c**oo**l; the pull bar **50**$_S$ and associated non-repeat bar **76**$_S$ control the type bar for the **s** sound in **s**eal; the pull bar **50**$_E$ and associated non-repeat bar **76**$_E$ control the type bar for the **e** sound in w**e**ll; and the pull bar **50**$_T$ and associated non-repeat bar **76**$_T$ control the type bar for the unvoiced stop consonant **t**. All of the code bars are assumed to be in their normal positions with each code bar being moved to the left as viewed in Fig. 4 by its associated electromagnet in accordance with the amplitude of the current from each rectifier D_1 to D_{10} for each phonetic sound. The slots in code bars B_1 to B_{10} which must be aligned by the proper movement of each code bar before pull bar **50**$_H$ can enter the code bars are designated H_1 to H_{10}, inclusive, and the corresponding slots for the associated non-repeat bar **76**$_H$ are designated H'_1 to H'_{10}; the slots in the code bars which must be aligned for the entrance of pull bar **50**$_U$ and non-repeat bar **76**$_U$ are designated respectively U_1 to U_{10} and U'_1 to U'_{10}; the corresponding slots for pull bar **50**$_S$ and non-repeat bar **76**$_S$ are designated S_1 to S_{10} and S'_1 to S'_{10}; the corresponding slots for pull bar **50**$_E$ and non-repeat bar **76**$_E$ are designated E_1 to E_{10} and E'_1 to E'_{10}; and the corresponding slots for pull bar **50**$_T$ and non-repeat bar **76**$_T$ are designated T_1 to T_{10} and T'_1 to T'_{10}.

An examination of the curves of Figs. 4, 11, 12, 23 and 25 of my above-mentioned copending application when integrated over each subband for the five sounds whose pull bars are shown on Fig. 4 will show that the relative energy values for the various subbands are such that the ten code bars in response to these five sounds will be moved distances proportional to the integers given in the following table if we arbitrarily assign the value of sixteen units of distance as the maximum distance any code bar will be moved for any subband of the designated five sounds:

Analyzed sound	Code bars									
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
t sound in ten	0	0	0	0	0	0	0	8	14	3
e sound in well	0	1	1	1	0	4	1	1	0	0
s sound in seal	0	0	0	0	0	1	3	4	16	16
u sound in cool	3	6	4	2	1	1	2	5	3	1
h sound in here	0	0	2	3	3	5	4	4	1	0

Thus if we assume for the **s** sound in seal that each of the code bars B_9 and B_{10} moves $^{16}/_{64}$ of an inch, then code bar B_8 will move $^{4}/_{64}$ of an inch, code bar B_7 will move $^{3}/_{64}$ of an inch, code bar B_6 will move $^{1}/_{64}$ of an inch, while there will be no appreciable movement of code bars B_1 to B_5; and hence slots S_1 to S_{10} for pull bar **50**$_S$ and slots S'_1 to S'_{10} for non-repeat bar **76**$_S$ should be so located that they will be aligned when moved the distances just specified. On a similar assumption for the **e** sound in well, code bars B_2, B_3, B_4, B_7, B_8 will each be moved $^{1}/_{64}$ of an inch, code bar B_6 will be moved $^{4}/_{64}$ of an inch, while there will be no appreciable movement for code bars B_1, B_5, B_9 and B_{10}; and hence slots E_1 to E_{10} for pull bar **50**$_E$ and slots E'_1 to E'_{10} for non-repeat bar **76**$_E$ should be so located that they will be aligned when moved the distances just specified. On a similar assumption for the **t** sound in **t**en there will be no appreciable movement of code bars B_1 to B_7, inclusive, while code bar B_8 will move $^{8}/_{64}$ of an inch, code bar B_9 will move $^{14}/_{64}$ of an inch, and B_{10} will move $^{3}/_{64}$ of an inch; and hence slots T_1 to T_{10} for pull bar **50**$_T$ and slots T'_1 to T'_{10} for non-repeat bar **76**$_T$ should be so located that they will be aligned when moved the distances just specified. It will be apparent from the examples just cited how one should locate the corresponding slots in the code bars for the other thirty-three sounds listed in the earlier part of this specification.

A few comments may be noted as to the general character of the slots in the code bars for receiving the pull bars and the non-repeat bars. The width of each pull bar slot with respect to the width of a pull bar will be determined by how much tolerance should be allowed for possible variations in the movement of any code bar in response to the same phonetic sound. In Fig. 4 it may be assumed that the mouth of each pull bar slot is about twice the width of each pull bar. Each pull bar slot should have fairly steep side walls. However, for the non-repeat bars the slots should be relatively shallow with gradual sloping side walls in order to reduce the force required to move one of the non-repeat bars out of the slots for each new alignment of the code bars. In locating the ten slots in the code bars for each of the thirty-six phonetic sounds, suitable precautions must be taken in their location along the code bars whereby when the ten slots for any one sound are aligned no corresponding alignment will occur for the ten slots for any other pull bar. This should not present any difficulty as is brought out by the consideration of the phonetic nature of speech and the large number of possible selections available. If we assume we can get ten recognizable steps in energy level in each of the ten frequency bands then we have a total of ten billion recognizable phonetic elements as against only thirty-six needed. Furthermore, the nature of speech is such that these thirty-six sounds differ from one another as much as possible. The steps provided in the present application provide for a far greater selection than is needed. This excess may be used advantageously in several ways. Some sounds are spoken a little differently from section to section of the country and by people differing in age, sex, culture, etc. Variations of this nature can be allowed for so that all possible selections are available, that is, a greater degree of selection may be utilized. Again, for certain sounds it may be desirable to have several forms recognized, making the total more than thirty-six but having two or more type bars print the same sound. For example, various pronunciations of **r** might be thus provided for or the various pronounced forms might be printed separately where this information was desired. With such a large number of selections available further modifications of the mechanism may be made to stress the differences between sounds which are commonly misunderstood, such as **f** and **th**.

A large amount of the extra selectivity available over what is needed will be taken up in designing for smoother operation of the pull bars in testing on the code bars. As the pull bars come in to test, either all will fail to enter sufficiently for typing operation or all but one will fail to enter. The pull bars that fail to enter will be stopped by having some part of the pull bar strike a single code bar, the first code bar encountered by the pull bar. The pull bar that enters the code bars goes all the way in until stopped by the stationary cam 72 as in Fig. 7, so that it does not contact with any code bar. The rejected pull bars in contacting the code bars will offer some resistance to the motion of the code bars. This will not be serious, however, because of the fewness of these contacts, because each contact period is of short duration, and finally because the code bars are moving at slow syllabic rates so that the amount of travel is small during the normal contacting period. However, consideration should be given to the mechanical design of the pull bars and the code bars to insure smooth operation. In the first place the pull bars may be permitted to bounce back slightly after contact with the code bars. In the second place a slight amount of bending in a rejected pull bar may be permitted when the pull bar contacts with the code bars. It may also be desirable to provide rounded edges at the contacting points between the code bars and the pull bars and provide for a minimum friction at such points by having smooth surfaces with lubrication by an oil film or graphite or special metal surfaces as needed.

In the mechanism disclosed in Fig. 2 it is assumed that the successive actuation of the thirty-six type bars 62 will print their symbols upon an elongated strip of paper carried by the platen 71. The main bail plunger 60 has an indent 151 for receiving a roller 152 carried by the spacing operating lever 153. Roller 152 is held against indent 151 by spring 154 so as to ride into and out of indent 151 as the plunger 60 moves up and down. Attached to the lower part of lever 153 is the spacing feed pawl 155 which is constantly forced into engagement with the teeth of the spacing ratchet wheel 156 by spring 157. Ratchet wheel 156 is mounted upon shaft 158, geared to the platen shaft 159 by gears 160, 161. Mounted upon shaft 158 is the platen wheel 71 which cooperates with a feed roller 162 held against platen 71 under pressure by spring 163 for spacing or feeding the message tape (not shown) one letter space at a time for each movement of plunger 60. The above-described manner of controlling rotatable platen 71 is disclosed more fully in the Lang et al. U. S. Patent 2,106,805.

The above-described arrangement for moving platen 71 one step for each upward excursion of plunger 60 will mean that occasionally there will be gaps between the symbols representing a single spoken word and occasionally there may be no blank space between the last symbol for one word and the first symbol of the succeeding word but such irregularities will not interfere with the intelligibility of the printed message. It will, in fact, correspond to the usual condition of hearing of speech sounds. However, if desired, the apparatus may be arranged to have the message tape advanced only after a symbol is printed.

The preferred form of this invention not only prints phonetic symbols on the message tape corresponding to the speech sounds received by microphone 20 but also registers on the tape the volume and pitch of the spoken sounds. It will be noted that the output from microphone 20 is also supplied to a branch circuit 168 leading to an amplifier 169, a network 170 and rectifier 171 with the output current of rectifier 171 by conductors 172 supplied to an electromagnet 173. Network 170 is designed to give a proper loudness weighting for different frequencies so that the output current from rectifier 171 will be a measure of the loudness of the speech sounds received by microphone 20, whereby the amplitude of the rectified current from rectifier 171 will increase with increase in the volume of the sound. The weighting of different frequencies for loudness contribution may be taken from Fig. 109 of a book by Harvey Fletcher on "Speech and Hearing" published in 1929 by Van Nostrand. As shown in Fig. 2, the platen assembly has a variable printing position determined by the volume indicator electromagnet 173. The armature of electromagnet 173 is coupled to an extension 174 of the platen assembly and the printing position of platen 71 with electromagnet 173 deenergized is determined by the biasing spring 175 which pulls extension 174 and platen 71 rearwardly until adjustable screw 176 contacts with stop 177. However, the electromagnet 173 in attracting its armature moves the platen assembly forwardly an amount dependent upon the loudness of the speech received by microphone 20, and hence the symbols typed on the tape 186 (Fig. 3) carried by platen 71 will not be along a horizontal line but the printing line 187 will have an upward slope if the spoken sounds are of increasing loudness and will have a downward slope if the sounds are of decreasing loudness. Thus if the phrase "This is phonetic printing" is spoken into microphone 20 with variable loudness, the record when printed in symbols of the International Phonetic Alphabet may be that shown in Fig. 3 for the case of operating at full speed.

Referring back to Fig. 1 it has already been pointed out that the amplitude of the output current from filter 24 is proportional to the pitch of the fundamental frequency of each voiced sound. Electromagnet 166 is connected across the output terminals of filter 24 and hence the force exerted by electromagnet 166 on its armature 167 is proportional to the pitch of each voiced sound. As shown in Fig. 2 electromagnet 166 is mounted on the platen 70 and is movable therewith. The armature of electromagnet 166 is coupled to one arm of a lever 180 pivoted about pin 181 on the platen assembly and biased by spring 182 to a position determined by stop screw 183. Pivoted to lever 180 is an arm 184 carrying a pen or pencil 185 for tracing a line on the message tape carried by platen 71. The relative position of the trace 188 made by pen 185 on the message tape 186 is, therefore, controlled by electromagnet 166 and hence an increase in the pitch of the voiced sounds received by microphone 20 will cause pen 185 to trace a line having an upward slope while a decrease in the pitch of the voiced sounds will give the traced line a downward slope. It is, therefore, apparent that due to electromagnets 166 and 173 with their associated apparatus, the message tape on platen 71 will carry a record not only of the symbols representing the spoken sounds but also a record of variations in the loudness and pitch of the talker.

Channel 23 of Fig. 1 will now be briefly explained whereby the current output of filter 24 has an amplitude proportional to the pitch of the fundamental frequency of the voiced sounds. Band-pass filter 190 selects the band from 50 cycles to 500 cycles per second of the speech currents so as to be sure to include two harmonics of the fundamental frequency for any voiced sound of low pitch and the fundamental frequency of any voiced sound of high pitch. The frequencies passed by filter 190 are passed through a fundamental frequency discriminating circuit 191 which has a loss increasing with the frequency for the purpose of insuring that the fundamental frequency comes out at a higher level than any harmonic thereof that may be present. For practical purposes this purifies the fundamental tone. Next, the output from equalizer 191 is fed to a frequency meter 192 which may be similar to that described in the copending application of R. R. Riesz, Serial No. 100,291, filed September 11, 1936. The fundamental frequency may be any fundamental frequency of speech, say, between 50 cycles and 500 cycles per second. As described in the Riesz application the output of the frequency meter 192 comprises a number of pulses of substantially uniform size, there being one such pulse for each cycle of the fundamental frequency which varies at a syllabic frequency rate. The output from frequency meter 192 is then sent through the low-pass filter 24 cutting off at 20 cycles per second, so that the unwanted frequency components are eliminated.

There remains to be discussed the frequency of operation of the main bail 61. Tests have indicated that a moderate rate of talking will give about 400 phonetic letters per minute which means an actuation of type bars 62 at the rate of about 400 per minute. This compares favorably with teletypewriter operation where speeds as high as 600 characters per minute have been obtained in page printing and about twice this rate for tape printing. Part of the mechanism of Fig. 2 must operate faster than the actual typing rate on the message tape. The apparatus of Fig. 2 is set up to test the code bars at fixed intervals of time and these time intervals should be short enough that the shortest speech sound will be examined and recorded. Tests indicate that the fastest talker speaking intelligibly cannot say more than 1500 sounds a minute. If we assume that the pull bars should be operated, say, twice per sound at this high speed with correspondingly increased testing at lower speeds then the main bail 61 should be operated at the rate of about 3000 operations per minute with the type bars working at a maximum of about 1500 per minute.

While the apparatus of Figs. 1 and 2 has been disclosed with special auxiliary devices such as a non-repeat bar, a voicing lock electromagnet 32, a stop consonant lock electromagnet 34, a pitch indicator electromagnet 166, and a volume indicator electromagnet 173 it is to be understood that one or more of these devices may be omitted if desired. In particular all of the apparatus of Fig. 1 surrounded by dotted line 200 may be omitted, in which event the output terminals of vogad 21 may be connected directly to the input terminals of the parallel connected filters F_1 to F_{10}. In the case of a reasonably constant calling level the vogad 21 may be omitted entirely or replaced with a potentiometer which the talker can adjust to his calling level as he starts to talk. While the volume indicator and the pitch indicator have been arranged to make certain types of records on the message tape it is obvious that electromagnets 166 and 173 may control the record in various other ways to produce indications of variations in the volume and pitch of the spoken sounds. It has been convenient to disclose printing the phonetic symbols on a message tape but the invention is not so limited as page printing may also be employed if desired. While applicant has preferred to divide the speed frequency band into ten subbands of frequency ranges indicated by filters F_1 to F_{10} it is to be understood that the frequency range of importance in speech may be divided into a greater or a smaller number of channels with substantial modifications of the band transmitted through each channel over the frequencies designated in Fig. 1. For example, in the case of typing a message received over a typical telephone line passing from 250 to 3000 cycles per second the lowest frequency band and the three highest frequency bands into which the speech range is divided by the band-pass filters of Fig. 1 would contain essentially no energy so that these bands could be omitted; and for such use it would be desirable to still divide the speech range from 250 cycles to 3000 cycles per second into ten subbands differing substantially from those illustrated in the circuit of Fig. 1.

While this invention has been disclosed as applied to message tape printing it will be obvious that the invention may be utilized with page printing apparatus. It may also be desirable for certain purposes to have the message tape fed forward each time a symbol is printed rather than each time the main bail is moved upwardly.

It will also be understood that this invention may be used in connection with the printing of sounds other than speech sounds such as the printing of symbols representing music either vocal or instrumental.

What is claimed is:

1. A sound printing system comprising a transmitter for transforming vocal sounds into electrical waves, means for amplifying said waves to a varying degree to compensate for any slow variations in the loudness of the sounds reaching said transmitter whereby a relatively constant volume is attained from the output of said amplifying means, means for dividing the amplified waves into a plurality of subbands of frequency, and printing mechanism selectively controlled by the average energy level in the various subbands.

2. A sound printing system comprising a transmitter for transforming vocal sounds into electrical waves, means for amplifying said waves to a varying degree to compensate for any slow variations in the loudness of the sounds reaching said transmitter whereby a relatively constant volume is attained from the output of said amplifying means, means for dividing the amplified waves into a plurality of subbands of frequency, a plurality of movable elements one for each frequency subband, each of said elements being biased to a definite position, means for moving each of said elements to any one of a plurality of advanced positions in accordance with the average energy level in one of said subbands for each voiced sound, and printing mechanism selectively controlled by said last means.

3. Apparatus for translating spoken sounds into printed words comprising a transmitter for transforming said sounds into electrical waves, an equalizer network for subjecting said waves to a transmission loss which decreases with frequency to compensate for the relatively low amplitude of the upper harmonics of the fundamental frequency of a voiced sound, means for transmitting said waves through said network when said waves represent a voiced sound while rendering said network ineffective when said waves represent an unvoiced sound, means for dividing said

waves into a plurality of subbands of frequency and printing mechanism selectively controlled by the average energy level in the various subbands.

4. A sound printing system comprising a transmitter for transforming vocal sounds into electrical waves, means for amplifying said waves to cause said waves to have a substantially constant energy level for successively spoken words to compensate for any variations in the loudness of the talker, means for dividing said waves into a plurality of subbands of frequency, printing mechanism comprising a plurality of type bars, a control bar individual to each type bar, certain of said control bars corresponding to voiced sounds and other control bars corresponding to unvoiced sounds, means for selectively actuating said control bars one at a time in an order determined by the relative energy levels in said frequency subbands for the successively spoken sounds, and means effective when said waves represent an unvoiced sound for preventing the actuation of any of said certain bars.

5. A sound printing system comprising a transmitter for transforming vocal sounds into electrical waves, means for amplifying said waves to have a substantially constant energy level for successively spoken words to compensate for any variations in the loudness of the talker, means for dividing said amplified waves into a plurality of subbands of frequency, printing mechanism comprising a plurality of type bars, certain of said type bars being for voiced sounds, other of said type bars being for unvoiced sounds, means for selectively actuating said type bars in accordance with the relative energy levels in said frequency subbands, and means effective when the waves impressed upon said amplifying means represent an unvoiced sound for preventing the accidental actuation of one of said certain bars.

6. A sound printing system comprising a transmitter for transforming phonated sounds into electrical waves, means for dividing said waves into a plurality of subbands of frequency printing mechanism comprising a plurality of type bars, certain of said type bars representing sounds having a discrete frequency spectrum, other of said type bars representing sounds having a substantially continuous frequency spectrum, means for selectively actuating said bars in accordance with the relative energy levels in said frequency subbands, means normally locking said certain bars, and means responsive to a sound wave having a discrete frequency spectrum for unlocking said certain bars.

7. A sound printing system comprising a transmitter for transforming speech sounds into electrical waves, means for dividing said waves into a plurality of subbands of frequency, printing mechanism comprising a plurality of type bars, certain of said bars representing stop consonant sounds, other of said bars representing other types of sounds, means for selectively actuating said bars in accordance with the relative energy levels in said frequency subbands, means normally locking said certain bars, and means responsive to a stop consonant sound received by said transmitter for unlocking said certain bars.

8. Apparatus for translating spoken sounds into printed words comprising a transmitter for transforming said sounds into electrical waves, means for dividing said waves into a plurality of subbands of frequency, a plurality of movable code bars one for each subband, means for actuating each code bar in accordance with the average energy level in one of said subbands whereby said code bars for each actuation assume relative positions which collectively define the sound initiating their actuation, a plurality of type bars each representing a different voiced or unvoiced sound, and means for testing said code bars in their advanced positions to select a type bar representing the sound defined by the relative positions of said code bars and for causing a printing operation by the selected type bar.

9. Apparatus for translating into printed symbols a complex electrical wave representing phonated sounds having not more than one fundamental frequency at any given instant, comprising means for selecting a number of substantially independent characteristics of said wave, a plurality of movable code bars each controlled in position by the syllabic variations of one of said characteristics whereby for each portion of said wave representing a separate sound said code bars assume positions collectively defining said sound, and printing mechanism selectively controlled by said code bars.

10. Apparatus for translating a complex electrical wave representing speech into printed words comprising means for selecting a set of substantially independent parameters corresponding in number to the number of the important independently movable elements of the vocal system involved in speech production, means for assigning to each of said parameters a value independently controlled by the syllabic rate of change of an essential characteristic of said wave, a plurality of movable code bars each biased to a definite normal position and adapted to be moved to any one of a plurality of advanced positions, each of said bars being controlled in position by the value of a different one of said parameters for each speech sound, and printing mechanism selectively controlled by said code bars.

11. Apparatus for translating a complex electrical wave representing speech into printed words comprising means for amplifying said wave to cause the wave to have a substantially constant energy level for successively spoken words to compensate for variations in the loudness of the talker, means for selecting a set of substantially independent parameters corresponding in number to the number of the important independently movable elements of the vocal system involved in speech production, means for assigning to each of said parameters a value independently controlled by the syllabic rate of change of an essential characteristic of said amplified wave, and printing mechanism selectively controlled by the syllabic variations in the values of said parameters.

12. Apparatus for translating into printed symbols an electrical wave representing phonated sounds comprising means for dividing said wave into a plurality of frequency subbands, means for rectifying the energy in each subband, a plurality of movable code bars one for each frequency subband, each of said bars being biased to a normal position, means for actuating each of said code bars to any one of a plurality of advanced positions in accordance with the rectified current from a different one of said subbands whereby the extent to which each bar is advanced is a measure of the amount of power in the frequency subband, and printing mechanism selectively controlled by said code bars.

13. Apparatus for translating into printed words a complex electrical wave of a wide band of frequencies representing speech, comprising

means for dividing said wave into a plurality of frequency subbands, means for rectifying the energy in each subband, a printing bail, a plurality of pull bars adapted to be operated by the printing bail, a plurality of code bars whose relative positions at any given instant define which pull bar will be actuated by said bail, each code bar being biased to a normal position and adapted to be advanced to any one of a plurality of advanced positions, and means for advancing each code bar to that one of its possible advanced positions which defines the relative amplitude of the rectified current from a different one of said subbands.

14. Apparatus for translating into printed words a complex electrical wave of a wide band of frequencies representing speech, comprising means for dividing said wave into a plurality of frequency subbands, means for rectifying the energy in each subband, a printing bail, a plurality of pull bars adapted to be operated by the printing bail, a plurality of code bars for selecting the particular pull bar to be operated at a given instant, means for setting each of said code bars in accordance with the amplitude of the rectified current from a different one of said subbands, certain of said pull bars representing a voiced sound, others of said pull bars representing an unvoiced sound, means for locking said certain pull bars against accidental operation by said bail when the particular setting of said code bars defines an unvoiced sound, and means controlled by the voiced portions of said complex wave for releasing said locking means.

15. Apparatus for translating into printed words a complex electrical wave of a wide band of frequencies representing speech sounds, said apparatus comprising means for dividing said wave into a plurality of frequency subbands, a plurality of selectors, means for shifting each selector in accordance with the average energy level in one of said subbands whereby said selectors assume certain relative positions for that portion of said wave representing one speech sound and assume different relative positions for that portion of said wave representing the succeeding speech sound, a plurality of type bars, one representing said first speech sound, means responsive to the shifting of said selectors to said certain positions for actuating said one bar, and means for preventing a second actuation of said one bar during the time interval said selectors remain stationary in said certain relative positions.

16. Apparatus for translating into printed words a complex electrical wave representing speech sounds comprising a plurality of selectors, means for shifting said selectors to certain relative positions defining that portion of said wave representing said one speech sound and for subsequently shifting said selectors to different relative positions defining that portion of said wave representing the next succeeding speech sound, a plurality of type bars one of which represents said first speech sound, means responsive to the arrival of said selectors to said certain positions for actuating said one type bar, and means for preventing a second actuation of said one bar during the time interval said selectors remain stationary in said certain relative positions before assuming different relative positions.

17. Apparatus for translating into printed words a complex electrical wave representing speech sounds, comprising a plurality of selectors, means for controlling said selectors in accordance with the portion of said wave representing each speech sound, a plurality of type bars, a record sheet, means controlled by said selectors for selectively actuating said type bars to strike said sheet, and means for indicating on said sheet variations in the pitch of those portions of said wave representing voiced speech sounds.

18. Apparatus for translating into printed words a complex electrical wave representing speech sounds, comprising a plurality of selectors, means for controlling said selectors in accordance with the portion of said wave representing each speech sound, a plurality of type bars, a record sheet, means controlled by said selectors for selectively actuating said type bars to strike said sheet, and means for indicating on said sheet variations in said wave representing variations in the relative loudness of the speech sounds.

19. Apparatus for translating into printed symbols a complex electrical wave representing speech sounds comprising means for modifying the portions of said wave representing voiced sounds to increase the amplitude of the harmonic frequencies relative to the amplitude of the fundamental frequency, a set of selectors, electrical means responsive to the modified voice portions of said wave and to the unmodified unvoiced portions of said wave for controlling said selectors to assume successive conditions defining the various speech sounds, a plurality of type bars and means controlled by said selectors for selectively actuating said type bars.

20. Apparatus for translating into printed words a complex electrical wave representing a succession of spoken words uttered with a varying degree of loudness, said apparatus comprising means for amplifying said wave to cause that portion of said wave representing one word to have substantially the same energy level as other portions of said wave representing other words, a set of selectors, electrical means responsive to the amplified wave for controlling said selectors to assume successive conditions defining the various speech sounds, a plurality of type bars, and means controlled by said selectors for selectively actuating said type bars.

21. Apparatus for translating into printed words a complex electrical wave representing speech sounds, a set of selectors, means for shifting said selectors to positions defining that portion of said wave representing a certain unvoiced sound, a plurality of type bars one representing said unvoiced sound, a second type bar representing a voiced sound, means responsive to said shifting of said selectors to cause a printing operation by said one type bar and means for preventing a printing operation by said second bar while said selectors occupy said shifted positions defining said certain unvoiced sound.

22. Apparatus for translating into printed words a complex electrical wave representing speech sounds comprising means for amplifying said wave to a varying degree to compensate for difference in the energy levels of portions of said wave representing different words, an electrical network having a loss decreasing with increase in frequency, means for causing voiced portions of said wave to traverse said network and for causing unvoiced portions to by-pass said network, a set of selectors, electrical means for controlling said selectors, means for controlling said electrical means in accordance with the output of said network for voiced sounds and in accord-

ance with the unvoiced portions of said wave bypassing said network whereby said selectors are successively conditioned to collectively define each different speech sound represented by said wave, and printing mechanism selectively controlled by said selectors.

23. Apparatus for translating into printed words a complex electrical wave representing speech sounds, said apparatus comprising a plurality of notched code bars, means for selectively shifting said bars to cause said bars to successively assume positions collectively defining each different speech sound represented by said wave, a plurality of type bars, an actuating lever individual to each type bar and movable into and out of engagement with said code bars, and means for periodically moving all of said levers into engagement with said code bars and for causing a printing operation by any type bar whose actuating lever enters the notches in said code bars.

24. Apparatus for translating into printed words a complex electrical wave representing speech sounds, comprising a plurality of code bars containing spaced notches on corresponding surfaces of each bar, a series of spaced test bars one for each phonetic sound to be printed, means for periodically urging said test bars towards the notched surfaces of said code bars, means responsive to the portion of said wave representing each speech sound for selectively actuating said code bars to align a notch in each code bar to permit the entrance into the aligned notches of that test bar representing the sound defined by the particular alignment of the notches, and printing means controlled by the entrance of any test bar in said notches.

25. Apparatus for translating into printed words a complex electrical wave representing speech sounds, said apparatus comprising a plurality of code bars containing spaced notches on corresponding surfaces of each bar, a series of spaced test bars one for each phonetic sound to be printed, means for periodically urging said test bars towards said notched surfaces and for subsequently withdrawing said test bars, means responsive to the portion of said wave representing each speech sound for selectively actuating said code bars to align the notches in said code bars to permit the entrance into the aligned notches of that one test bar representing the sound defined by the particular alignment of the notches, printing means controlled by the entrance of any test bar in the aligned notches, and means effective for the duration of said particular alignment of said code bars for preventing a second entrance of said one test bar into said notches.

HOMER W. DUDLEY.