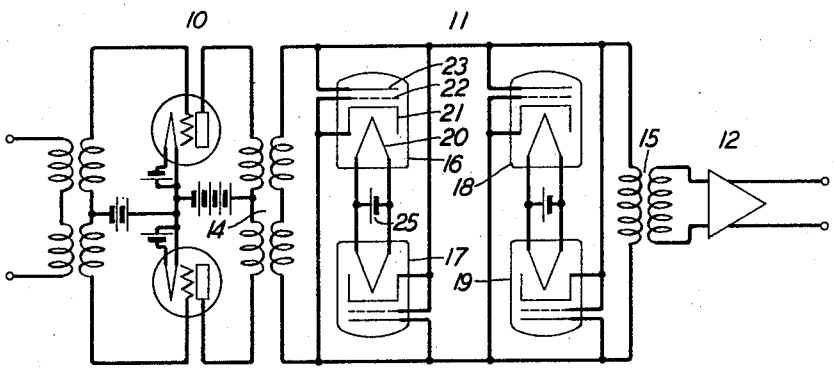
May 16, 1933. H. CHRISTENSEN 1,909,810

TELEPHONY

Filed March 19, 1931

FIG. 1



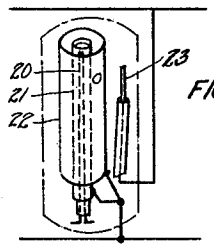


FIG. 1a.

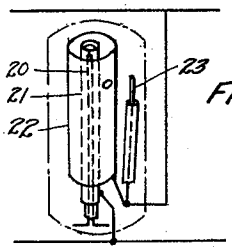
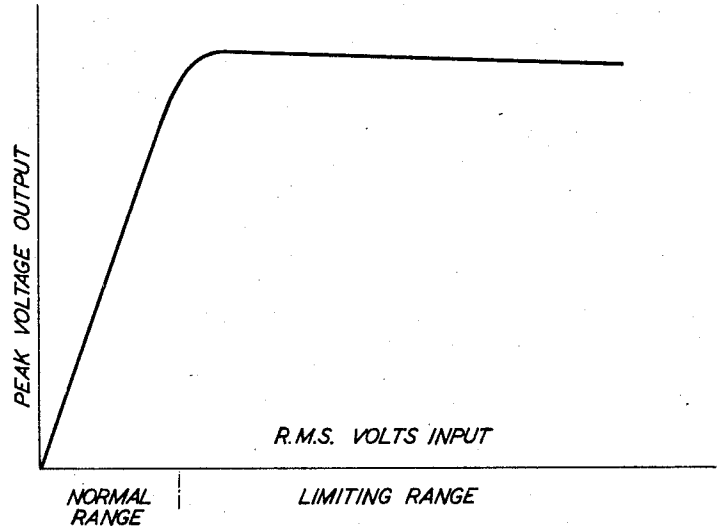


FIG. 1b.

FIG. 2



INVENTOR
H. CHRISTENSEN
BY
W. A. Burgess
ATTORNEY

Patented May 16, 1933 1,909,810

UNITED STATES PATENT OFFICE

HOWARD CHRISTENSEN, OF NEW YORK, N. Y., ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

TELEPHONY

Application filed March 19 1931. Serial No. 523,665.

The present invention relates to peak voltage limiting circuits employing space discharge devices and has particular reference to voltage limiters for use in circuits carrying alternating current for signaling purposes such, for example, as speech currents.

Voltage limiters of the shunt type are known in the prior art as evidenced, for example, by Arnold Reissue Patent No. 14,585, reissued January 14, 1919.

The present invention represents an improved type of voltage limiting circuit employing hot-cathode gas-filled discharge tubes as shunting elements across the circuit on which the peak voltage is to be limited. The present invention was evolved in connection with development work on a speech transmitting circuit working at high energy level as, for example, in the input circuit to a system of very high attenuation such as a transoceanic telephone cable system. In systems of this character, not only is it very important that the voltages be limited within the prescribed voltage range, but it is almost equally important from the standpoint of quality of transmission that the voltage limiting device shall not introduce distortion. When the system is operating within the normal voltage range the low distortion in transformers, power amplifiers and other elements of the system is of very little avail if the voltage limiter of the circuit introduces large distortion. It was found when attempting to use prior art types of voltage limiters in a high quality telephone circuit that the relatively large distortion factor of the limiters rendered them unsuitable or else the limiting action after voltage limiting began to occur was not sufficiently constant.

Hot-cathode, gas-filled discharge devices have been developed which possess a linear input-output voltage characteristic over a voltage range up to a certain critical voltage and a practically constant voltage characteristic for applied voltages in excess of this critical value.

The present invention utilizes hot-cathode, gas-filled tubes of this type in a novel manner to provide an effective voltage limiting circuit possessing high quality of transmission over the normal voltage range and substantially a flat characteristic over the limiting range.

The various features and objects which characterize the present invention will be more clearly understood from the following detailed description of certain typical embodiments thereof as illustrated in the accompanying drawing.

Referring to the drawing Fig. 1 shows a speech amplifying and voltage limiting circuit embodying the invention;

Figs. 1*a* and 1*b* are sketches showing a type of tube structure suitable for use with the invention, with the tube elements differently connected in the two figures; and

Fig. 2 shows characteristics obtained with the circuit of Fig. 1.

The circuit of Fig. 1 is a high power speech amplifying and limiting circuit suitable for use, for example, in transmitting into a line of high attenuation such as a transoceanic cable and may find application in terminal circuits for cables, such as are shown in the U. S. application of A. M. Curtis, Serial No. 382,011, filed July 29, 1929 and Canadian Patent No. 326,431, issued September 27, 1932 or in the transmitting circuit disclosed in an application of Charles N. Nebel, Serial No. 459,663, filed June 7, 1930 and Canadian Patent No. 321,305, issued April 5, 1932.

The circuit of Fig. 1 shows an initial push-pull amplifier stage 10 supplied with speech waves from any desired or suitable source, a peak voltage limiting circuit 11, and a power amplifying stage 12, the output of which is assumed to lead to the transmission path such as the deep sea telephone cable. Amplifiers 10 and 12 may be of the usual prior art construction.

The voltage limiting circuit 11 is connected between the output transformer 14 of preliminary amplifier 10 and the input transformer 15 of power amplifier 12. This voltage limiting circuit comprises two pairs of hot-cathode gas-filled discharge tubes, each tube being connected in shunt across the two sides of the line, and the tubes are

so poled as to limit both halves of the waves. One pair of tubes is shown as comprising tubes 16 and 17 while the other pair comprises tubes 18 and 19. These tubes may all be similar to each other in construction and each comprises a heater element 20, a cathode 21, a control element 22 and an anode 23. The cathode 21 of each of the tubes is heated by means of the heater 20 which in turn is supplied with heating current from a respective battery 25.

In the operation of the voltage limiting portion of the circuit the four tubes shown are all maintained with heated cathodes ready to transmit current instantly when the applied voltages between the cathode and anode are of proper magnitude and sign. The heating of the cathode is accomplished as stated by passing current from battery 25 through the heater element 20. Let it be supposed that a wave is transmitted to circuit 11 which makes the anode 23 of tube 16 positive with respect to its cathode 21. If this voltage rises to a value equal to the anode-cathode voltage of tube 16 at which current begins to flow, this current will flow across between anode 23 and cathode 21 to the opposite side of the line. It is a characteristic of the tube 16 that as soon as this current begins to flow the voltage between the anode 23 and cathode 21 and therefore the voltage across the line assumes a definite maximum value which is substantially constant notwithstanding that the applied voltage through transformer 14 may tend to increase. Any tendency of this voltage to increase results in a further lowering of the impedance of the space path of tube 16 and an increase in discharge current, but the terminal voltage remains substantially constant.

The relation between the applied voltage and the peak voltage in the output circuit of the voltage limiting circuit 11 is shown by the curve S of Fig. 2. As is seen from these curves there is a linear relation between the applied voltage and the output voltage over the normal operating range while for all voltages in excess of the normal range, the output peak voltage is maintained substantially constant.

It will be understood that on the opposite half cycle of the voltage waves impressed from the amplifier 10 onto the voltage limiting circuit 11, a tube, say tube 17, which is poled oppositely to the tube 16 will operate in the same manner as has been described of tube 16 so that both half cycles of the alternating voltage waves are limited in the same manner.

While a single pair of limiting tubes 16, 17 might be used, it is preferable to employ a reserve pair of tubes 18, 19 which may act similarly to tubes 16, 17 but which preferably have slightly different characteristics so that they do not operate except by failure of tubes 16 and 17. Even where two hot cathode gas-filled tubes such as 16 and 18 are connected in parallel in a circuit, it has been observed that only one of the tubes will as a rule become conductive. This is for the reason that the impedance of the tube drops to a very low value immediately upon the establishment of current flow through the tube. This fall of the internal impedance to a lower value prevents the anode voltage from rising to a higher value so that unless the second tube (such as 18) has already begun to conduct current it will not begin to conduct after the first tube (such as 16) has started to pass current. For this reason two substantially identically tubes 16 and 18 could be used and also tubes 17 and 19 could be substantially identical since only one pair of tubes 16, 17 or 18, 19 would be operative at the same time. However, by choosing for tubes 18 and 19 tubes which have slightly different characteristics the normal limiting will be accomplished by tubes 16, 17 and the tubes 18, 19 will serve as reserve tubes.

It was mentioned above that the tubes 16, 17, 18 and 19 are of the hot-cathode gas-filled type. These tubes are preferably of the type disclosed in an article entitled "Gas-filled Thermionic Tubes" by Albert W. Hull published in the transactions of the American Institute of Electrical Engineers, vol. 47, July, 1928, pages 753 to 763. The specific type of tube used by applicant with successful results is disclosed in a patent application in the name of A. L. Samuel, Serial No. 465,083, Filed July 1, 1930. Instead of the "Thyratron" or the three-electrode type of tube disclosed in the Samuel application, a tube having no controlling element, but only a cathode and an anode such as disclosed in the Hull article referred to, for example, may be used. As explained in the Hull article cathode disintegration can be reduced and long tube life can be obtained by observing the fundamental principle in the operation of the tube that the cathode potential drop must not exceed the critical value, sometimes called the disintegration voltage, above which cathode disintegration first begins to take place. This critical value lies between 20 and 25 volts for the common inert gases and is considerably above the ionizing potential. By proper design and use of the tubes as explained by Hull and Samuel respectively, tubes of this type can be made to have very large current carrying capacity and an active life of the order of 1,000 hours or greater.

In Figs. 1*a* and 1*b* there are reproduced in simplified form sketches showing the tube construction disclosed in the Samuel application referred to. The cathode 21 is in

the form of a pencil or rod which is coated with thermionically active material. The control element 22 is in the form of a cylinder with a hole in one side thereof through which the electrons may pass and the anode 23 is in the form of a wire which is placed opposite the hole in the cylinder. In the circuit arrangement of Fig. 1 having the characteristics disclosed in Fig. 2, it will be observed that the cylinder (shown dotted) is connected to the cathode in each case while the wire (anode) is connected to the respective side of the circuit 11. This mode of connection is illustrated in Fig. 1*a*. With this type of connection actual practice has shown the limit voltage is of the order of 24 to 25 volts.

The cylinder 22 may, if desired, be used as the anode in which case it is preferable to connect it to the wire 23, and to connect both the cylinder and the wire to the line conductor, as illustrated in Fig. 1*b*. In this case the limit voltage is of the order of 18 volts with the type of tubes used by applicant.

In any case, the voltage ratios of transformers 14 and 15 may be made such that the speech or other waves as they pass through circuit 11 occupy the normal operating voltage range (see curve of Fig. 2) and such that the desired maximum voltage for the circuit 11 coincides with the limiting voltage of 18 or 24 volts, as the case may be, obtainable with the tubes 16, etc. Of course, tubes having other characteristics than those described may be used if desired.

What is claimed is:

1. A peak voltage limiter for a circuit carrying alternating current of varying voltage comprising a pair of hot-cathode, gas-filled space discharge devices connected in shunt relation to said circuit and oppositely poled, having zero current linear voltage characteristics throughout the normal voltage range of the circuit, the voltage drop across each of said tubes for impressed voltages tending to exceed said voltage range being substantially constant and independent of the space current, whereby the voltages across the output of said circuit are confined to said normal range and within said range are a faithful replica of those impressed on the circuit.

2. A speech transmission circuit comprising an amplifier of low distortion, and a peak voltage limiter for confining the waves amplified by said amplifier to a given maximum voltage range, said limiter comprising a pair of hot-cathode, gas-filled discharge devices connected in shunt relation to said circuit and oppositely poled, the distortion produced by said limiter within the given voltage range being at least as low as that produced by said amplifier, said limiter having a substantially flat voltage characteristic for impressed voltages in excess of said range.

3. A peak voltage limiter for a speech transmission circuit for protecting the circuit from peak voltages in excess of the normal speech range, comprising two pairs of hot-cathode, gas-filled space discharge devices, the devices of each pair being connected in shunt relation to said circuit and being oppositely poled, each of the similarly poled devices having its maximum voltage limit at substantially the maximum peak speech voltage to be transmitted, whereby one pair acts as a reserve and effectively protects the circuit from voltages in excess of the normal speech range in case of failure of the other pair to function.

4. A peak voltage limiter for a speech transmission circuit for protecting the circuit from peak voltages in excess of the normal speech range, comprising a pair of hot-cathode, gas-filled space discharge devices connected in shunt relation to said circuit, each device having a substantially zero current linear voltage characteristic throughout a definite range from zero to a predetermined maximum, and a substantially constant terminal voltage characteristic for applied voltages in excess of said maximum, for all frequencies of importance in the speech range, and means to adjust the maximum permissible speech voltage to coincide with the predetermined maximum voltage characteristic of said devices.

In witness whereof, I hereunto subscribe my name this 18th day of March 1931.

HOWARD CHRISTENSEN.