

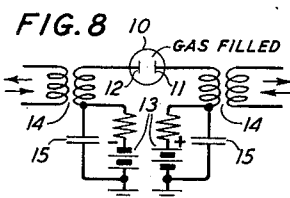
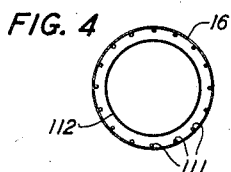
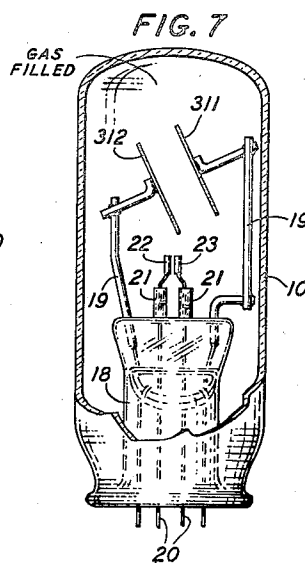
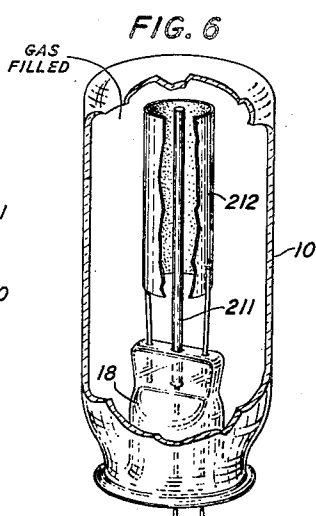
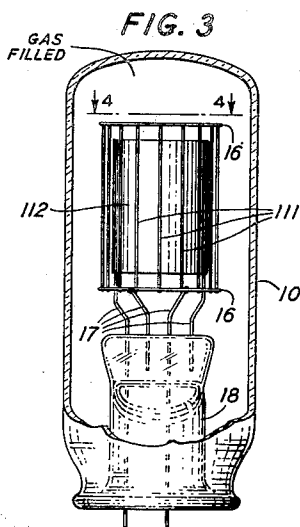
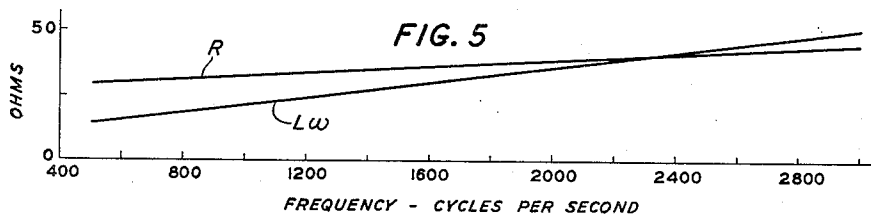
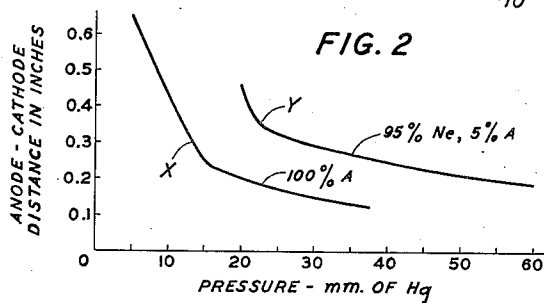
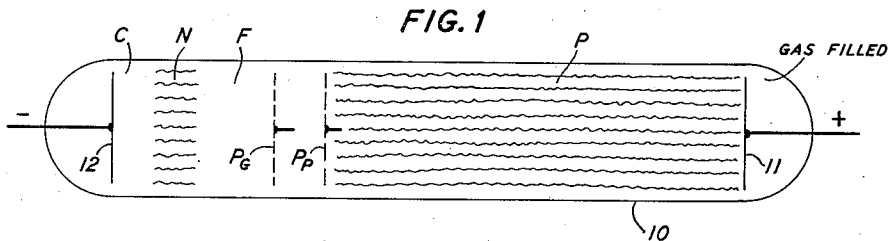
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GLOW DISCHARGE DEVICE

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GLOW DISCHARGE DEVICE

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1

This invention relates to glow discharge devices and more particularly to such devices especially suitable for use in speech and other signal transmission circuits.

In general, glow discharge devices comprise a cathode and an anode immersed in an ionizable medium, that is a gas or mixture of gases, at a pressure such that a discharge between the electrodes can be sustained upon maintenance of a prescribed potential difference between the electrodes. In such devices of presently known construction, when a direct current potential sufficient to sustain a discharge is impressed between the electrodes, the current through the device includes spurious variations or noise components. Some of these components may be suppressed or prevented by adjustment or design of the external circuit associated with the device. However, other components cannot be eliminated in this manner and, thus, impair the efficacy of the device for transmission of signals.

Among components of the latter type is an oscillatory noise of substantial amplitude which may be of complex wave form but is none the less repetitive. Its frequency spectrum varies from medium to medium. For example, in devices employing argon the oscillatory noise frequencies are in the audio range, specifically a few hundred to a few thousand cycles. For lighter gases, these frequencies are higher. It is evident that such noise deleteriously affects the signal to noise ratio for a glow discharge device utilized in a signal transmission path.

One object of this invention is to substantially eliminate noise, and particularly noise of the type above indicated, in glow discharge devices.

Another object of this invention is to improve the transmission characteristics of glow discharge devices and more specifically to realize a low impedance for such devices at audio frequencies.

It has been discovered that oscillatory noise is associated with the character of the region of the discharge path immediately adjacent the anode and that this, in turn, for a given gas, is dependent upon the gas pressure and the cathode to anode spacing. Furthermore, it has been discovered that a definite critical relationship between gas pressure and cathode to anode spacing exists for which oscillatory noise will not be produced. Specifically, for any given gas and gas pressure, if the cathode to anode spacing is below a certain magnitude, oscillatory noise will not be produced; conversely, for a given gas and electrode spacing, if the gas pressure is below a

2

certain value oscillatory noise will not obtain. The product of gas pressure and maximum cathode to anode spacing is approximately a constant over a range of pressures.

In accordance with one feature of this invention, accordingly, in a glow discharge device the gas pressure and cathode to anode spacing are correlated so that noise, particularly noise of the type above discussed, is eliminated.

In accordance with another feature of this invention, the cathode and anode are constructed and arranged so that during use of the device substantially all of the cathode emissive surface is active and the current density thereat is low, whereby a low impedance is obtained under conditions conducive to long cathode life.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a view, partly diagrammatic, of a glow discharge device, which will be referred to hereinafter in an analysis of certain principles involved in this invention;

Fig. 2 is a graph illustrating the relation between gas pressure and cathode to anode spacing in glow discharge devices illustrative of this invention;

Fig. 3 is an elevational view of a glow discharge device constructed in accordance with this invention, a portion of the enclosing vessel being broken away to show the internal structure more clearly;

Fig. 4 is a view of the electrodes in the device shown in Fig. 3 taken along the plane 4—4 of the latter figure;

Fig. 5 is a graph showing impedance characteristics of the device illustrated in Figs. 3 and 4;

Fig. 6 is an elevational perspective view of another illustrative embodiment of this invention, a portion of the enclosing vessel being broken away;

Fig. 7 is an elevational view of still another embodiment of this invention, a portion of the enclosing vessel being broken away; and

Fig. 8 is a circuit diagram illustrating one manner in which devices constructed in accordance with this invention may be utilized.

Referring now to the drawing, the glow discharge device illustrated in Fig. 1 comprises an enclosing vessel 10 having therein an ionizable atmosphere, such as a rare gas, at a low pressure, for example of the order of 50 millimeters of mercury or less. Mounted at one end of the

vessel is an anode 11 which may be a metallic disc. At the other end of the vessel is a cathode 12, for example a disc like the anode, parallel thereto and having the face thereof toward the anode coated with a highly electron emissive material, such as a known mixture of barium and strontium oxides.

A device of this type may be included in a speech or other intelligence transmitting circuit as illustrated in Fig. 8. Specifically, the cathode 12 and anode 11 may be biased by direct current sources such as batteries 13, relatively poled as shown, to produce between the electrodes a potential sufficient to initiate and sustain a discharge. The device is connected between two stations, e. g. subscribers' stations, by suitable transformers 14. The batteries are by-passed for the alternating current signals to be transmitted, by condensers 15.

If a direct current potential sufficient to sustain a discharge is impressed between the cathode and anode, it has been found that, in general, the current through the device includes more or less random variations or noise components. These variations may be classified, on the basis of oscillographic analyses, as (1) fluctuation noise, (2) spasmodic pulses of current and (3) an oscillatory type of noise.

The fluctuation noise, it has been ascertained, is due to the collision of charged particles, i. e. electrons or ions, with other charged particles or with uncharged particles such as gas molecules, and to the arrival or emission of charged particles at the electrodes. Its amplitude is relatively small so that this type of noise is negligible in many practical applications of glow discharge devices. For example, in a device of known construction it has been determined that this noise is of the order of 45 decibels below the permissible noise level in a local telephone transmission circuit.

The second type of noise, it has been ascertained, is associated with changes in the position of various parts of the discharge, which will be described in some detail hereinafter. Illustrative of such changes are a shift in the position of the negative glow relative to the cathode when all of the active cathode surface is not being utilized, and shifting of the positive column or anode glow. This type of noise is of substantial amplitude. It has been found that spasmodic current pulses due to shifting of the negative glow can be eliminated by operating the device under such conditions that the direct current through the device is sufficient to bring all of the active cathode surface into use.

The third or oscillatory type of noise is of relatively large amplitude. It may be of complex wave form. However, it is definitely repetitive. It appears impossible to eliminate such noise by changes in the external circuit associated with the device.

Noises of the second and third types, as has been indicated, are of substantial level, and, hence, result in serious distortion of any alternating current signals which are superimposed upon the direct current potential impressed across the device to initiate and sustain a discharge. For example, if a device of the type described is included in a telephone circuit in such relation that speech or other audio frequency signals pass therethrough, the noise noted results in an intolerable signal to noise ratio.

In accordance with one feature of this invention, noise of the third type and also noise of

the second type, particularly that associated with shifting of the positive column or anode glow, are eliminated. Specifically, this is effected by a unique correlation of the gas, gas pressure and cathode to anode spacing. It has been discovered that, for a given gas, for each gas pressure there is a critical maximum value of cathode to anode spacing for which noise of the third type and of the second type associated with shifting of the anode glow or positive column will not be produced and that conversely, for a given gas, for each cathode to anode spacing there is a maximum gas pressure for which such noise will not obtain.

The relationships for two typical gases in a device of the construction shown in Fig. 1 are illustrated in Fig. 2, curve X being for a gas filling of 100 per cent argon and the curve Y being for a gas filling of 95 per cent neon and 5 per cent argon. Each curve is based upon a multiplicity of noise measurements in devices such as shown in Fig. 1 but wherein the anode was movable to vary the cathode to anode spacing. The coordinates of any point on each curve X and Y are the gas pressure (abscissa) and the corresponding maximum cathode to anode spacing (ordinate) for which noise of the third type will not obtain. As is apparent, the greater the gas pressure the closer must the anode be spaced relative to the cathode to result in elimination of the noise. Conversely, the smaller the anode to cathode spacing, the higher is the gas pressure which may be employed without the creation of noise. The correlation of pressure and spacing in the manner illustrated in Fig. 2, it has been found, eliminates not only noise of the third type but also noise of the second type associated with shifting of the positive column or the anode glow. The product of the pressure and the maximum spacing for the prevention of noise is approximately constant for a given gas.

The relationship of gas pressure and cathode to anode spacing, illustrated in Fig. 2, requisite for absence of noise of the types above indicated has been found to obtain for a multiplicity of gases. The following table presents typical values illustrative of the relationship for a number of argon-neon mixtures in a device, such as shown in Fig. 1, having parallel disc electrodes. The spacing given is the maximum cathode-anode spacing permissible at that given pressure for the absence of oscillatory noise.

Gas	Pressure	Spacing
		Inches
1% argon—99% neon	60 mm. of Hg.	.28
10% argon—90% neon	do.	.18
30% argon—70% neon	40 mm. of Hg.	.15
50% argon—50% neon	30 mm. of Hg.	.15

It has been established that, for a given gas and gas pressure, the condition requisite for the elimination of the types of noise above indicated is that the anode be positioned in the Faraday dark space and so close to the cathode that anode glow does not obtain. That is to say, if in a glow discharge device, such as illustrated in Fig. 1, the anode is moved toward the cathode, the anode position at which oscillatory noise disappears is in the Faraday dark space and the beginning of the absence of noise coincides with the disappearance of the anode glow. The explanation for this, it is believed, is found in the following analysis of the conditions extant in a glow discharge device.

Referring to Fig. 1, if the anode is widely spaced from the cathode and the electrodes are energized to establish a discharge therebetween, the discharge path comprises several distinct regions. Specifically, immediately adjacent the cathode is the cathode dark space C. Successively this is followed, in the direction toward the anode, by the negative glow region N, Faraday dark space F and positive column P.

In the cathode dark space, across which most of the voltage drop across the device occurs, positive ions are produced and these bombard the cathode to cause release of electrons therefrom. Each electron thus released, under the influence of the potential gradient toward the anode, in its passage through the cathode dark space and into the negative glow, causes a number of ionizations. At least some of the ions thus produced flow back to and bombard the cathode, thereby to release other electrons. The process involved is repetitive so that a discharge can be sustained.

In the negative glow region, there is considerable ionization, due to electrons flowing from the cathode dark space. The ion and electron concentrations are substantially equal so that the potential drop is small.

By the time the electrons reach the Faraday dark space, their energy is substantially spent. Consequently, there is but limited ionization in this region. The ions and electrons in this space are supplied primarily by diffusion from the negative glow. Their concentration decreases with increasing distance from the negative glow. Also, both ions and electrons pass to the wall of the enclosing vessel. Consequently, the field in this region increases with increasing distance from the cathode and a position is reached where the electrons have sufficient energy to produce substantial ionization. This position marks the beginning of the positive column.

In the positive column, there is approximately equal concentration of electrons and positive ions. A relatively small gradient in this region is sufficient to cause ionization whereby ions and electrons are produced to replenish those lost to the enclosing vessel.

If the anode is moved sufficiently close to the cathode, the positive column may be caused to disappear, that is the anode is located in the Faraday dark space. The effects or conditions at the anode vary with the position of the anode in this space. If the anode is located in the Faraday dark space and relatively remote from the negative glow, the number of positive ions thereadjacent is small so that an electron space charge and an anode drop build up. If this drop is sufficiently high, and it increases with distance from the cathode, excitation or anode glow begins. This is followed by ionization. The ions produced reduce the electron space charge so that, as a result, the potential drop is substantially reduced or eliminated and the ionization ceases. Then the electron space charge begins to build up and the cycle is repeated. Manifestly, the conditions are such as to produce oscillation whereby noise of the third type heretofore noted is produced.

Now if the anode is moved still closer to the cathode, it will reach a position, in the Faraday dark space, where the ion and electron concentrations are high. At this position, because of the ions, no substantial electron space charge obtains adjacent the anode when the electrons are collected to produce the current in the external circuit between the anode and cathode. There

is, therefore, no substantial ionization or excitation and no anode glow obtains. In the absence of excitation and ionization, oscillatory noise is not produced.

It is clear from the foregoing analysis, and has been verified by tests on actual devices, that there is a definite line of demarcation between anode positions, in the Faraday dark space, at which oscillation will or will not occur. As the anode is moved toward the cathode, the oscillatory noise and anode glow disappear simultaneously. The condition requisite for prevention of oscillatory noise is that the anode be in the Faraday dark space and so close to the cathode that anode glow does not obtain.

It may be emphasized that there is a distinct difference between the anode-cathode spacings at which anode glow and the positive column begin. The relative locations of these two anode positions are indicated at P_G and P_P, respectively, in Fig. 1.

The anode glow is affected by several factors, such as the electrode geometry and the anode area. In general, if the anode area is decreased, the electron space charge density thereadjacent increases and the anode glow and oscillatory noise appear at a smaller cathode-anode spacing.

Several electrode geometries for devices constructed in accordance with the invention are illustrated in Figs. 3 to 6.

The glow discharge device illustrated in Figs. 3 and 4 comprises a cylindrical cathode 112, for example a nickel cylinder having a coating of barium and strontium oxide mixture on its outer surface, and an anode comprising a plurality of parallel, equally spaced wires or rods 111 of iron arranged in a cylindrical boundary coaxial with the cathode. The wires or rods 111 are mounted and held in the prescribed space relation by a pair of metallic rings 16. Rigid conductors 17 embedded in the stem 18 of the vessel 10 support the cathode and anode in coaxial relation. Significant parameters for a typical device of this construction and free of noise of the second and third types heretofore described are:

Cathode diameter (outer)— $\frac{3}{4}$ inch
Cathode to anode spacing—.010 to .020 inch
Gas—99 per cent neon, 1 per cent argon
Gas pressure—47 mm. of mercury
Sustaining voltage—53 volts

A particular further feature of the glow discharge device illustrated in Figs. 3 and 4 is the low impedance thereof. It has been found, in general, that in cold cathode glow discharge devices, for a steady direct current flowing through the device, the impedance of the device comprises both resistive and inductive components. It has been found further that, in general, the impedance of the device increases as the current decreases.

Theoretically, the impedance of a glow discharge device may be decreased by increasing the current flow through it. However, the life of common types of cold cathode devices with activated cathodes decreases rapidly with increase in such current. The impedance may be decreased somewhat also by increasing the gas pressure. However, this not only results in an increase in the current density but also increases materially the difficulty of obtaining a uniformly active cathode surface.

The construction illustrated in Figs. 3 and 4 enables attainment of low impedance without the

deleterious effects and practical disadvantages above noted. Because of the large cathode surface and the juxtaposition of the anode elements thereto, the cathode may be operated at a relatively low current density, just large enough that all of the cathode emissive surface is used. The resistive and inductive components of the impedance of a device of the construction shown in Figs. 3 and 4 and having the parameters set forth above are illustrated, over a range of audio frequencies, by the curves R and L_w, respectively in Fig. 5.

In the device illustrated in Fig. 6, a rod anode 211 extends axially of a cylindrical cathode 212, for example of sheet nickel having a coating of a mixture of barium and strontium oxides on its inner surface and having its outer surface calorized. In a specific embodiment, the cathode was of $\frac{3}{8}$ inch inner diameter and the anode was of 0.030 inch diameter nickel. For this construction, typical gas pressures which could be employed without appearance of oscillatory noise were found to be as follows:

Gas	Typical Gas Pressures in Millimeters of Mercury
Argon	Mm. 10 to 24
Krypton	10 to 32
Argon (5 per cent)—Neon (95 per cent)	30 to 50
Argon—Mercury Vapor Corresponding to Condensed Mercury Temperature of 25° C. to 80° C.	10 to 23
Argon (96 per cent)—Hydrogen (4 per cent)	10 to 23

In the embodiment of this invention illustrated in Fig. 7, the cathode 312 and anode 311 are parallel discs rigidly supported from the stem 18 by leading-in conductors 19. Also supported from the stem 18 by leading-in conductors 20 encircled by insulating sleeves 21 are a pair of closely adjacent auxiliary electrodes 22 and 23. These electrodes, which serve respectively as a control cathode and control anode, define a starter gap by the controlled breakdown of which a discharge between the main electrodes 311 and 312 may be initiated.

In a typical device of the construction illustrated in Fig. 7 and free of oscillatory noise in the discharge gap between the main electrodes 311 and 312, these electrodes were $\frac{5}{8}$ inch diameter discs, the cathode face toward the anode was coated with a mixture of barium and strontium oxides, these electrodes were spaced 0.25 inch and the gas was argon at a pressure of 15 millimeters of mercury. The main gap breakdown voltage was 224 volts.

Although specific embodiments of the invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A glow discharge device comprising an enclosing vessel having an ionizable medium therein, and a cathode and an anode within said vessel, the cathode to anode spacing and pressure of said medium being such that, when a potential difference between said cathode and anode sufficient to sustain a discharge therebetween obtains, said anode is in the Faraday dark space of the discharge and anode glow does not occur.

2. A glow discharge device in accordance with claim 1 wherein said anode and cathode have plane, parallel opposed faces.

3. A glow discharge device in accordance with claim 1 wherein said anode and cathode are cylindrical.

4. A glow discharge device comprising an enclosing vessel having a gaseous filling, and a cathode and an anode in parallel relation within said vessel, said anode being spaced such distance from said cathode that when a potential difference between said cathode and anode sufficient to sustain a discharge therebetween obtains, the anode is in the Faraday dark space of the discharge and anode glow does not occur.

5. A glow discharge device comprising a cathode and an anode, and an envelope enclosing said cathode and anode and having a filling comprising a rare gas therein, said anode being spaced from the cathode a distance such that when a sustained discharge exists between the cathode and anode the anode is in the Faraday dark space of the discharge, and said distance being less than that for which substantial ionization immediately adjacent said anode occurs.

6. A glow discharge device in accordance with claim 5 wherein said cathode and anode are plane and parallel.

7. A glow discharge device in accordance with claim 5 wherein said cathode and anode are cylindrical.

8. A glow discharge device in accordance with claim 5 wherein said rare gas is argon.

9. A glow discharge device comprising an enclosing vessel having therein a filling of argon at a pressure in the range between about 5 and 35 millimeters of mercury, and a cathode and an anode within said vessel and spaced a distance less than about 0.64 inch.

10. A glow discharge device comprising an enclosing vessel having therein a mixture of substantially 95 per cent neon and 5 per cent argon at a pressure in the range between about 20 and 60 millimeters of mercury, and a cathode and an anode within said vessel and spaced a distance less than about 0.46 inch.

11. A glow discharge device comprising an enclosing vessel having a gaseous filling, a cylindrical cathode within said vessel, and an anode comprising a plurality of parallel linear elements mounted in a cylindrical boundary coaxial with said cathode, the pressure of said filling and the spacing of said elements relative to said cathode being such that when a potential sufficient to sustain a discharge between said cathode and anode obtains, the anode is positioned in the Faraday dark space of the discharge and anode glow does not occur.

12. A glow discharge device in accordance with claim 11 wherein said gaseous filling is about 99 per cent neon and 1 per cent argon at a pressure of the order of 47 millimeters of mercury and said cathode and anode are spaced approximately 0.015 inch.

13. A glow discharge device comprising an enclosing vessel having a gaseous filling, a cylindrical cathode within said vessel, and a rod anode within and extending along the axis of said cathode, the pressure of said filling and the distance between said anode and cathode being such that when a potential between said cathode and anode sufficient to sustain a discharge therebetween obtains, the anode is located in the Faraday dark space of the discharge and anode glow does not occur.

14. A glow discharge in accordance with claim 13 wherein said filling is argon at a pressure of substantially 10 to 24 millimeters of mercury, the

inner diameter of said cathode is substantially $\frac{1}{8}$ inch and the diameter of said anode is substantially 0.03 inch.

15. A glow discharge device comprising an enclosing vessel having a gaseous filling, a plane cathode and a plane anode in parallel relation within said vessel and defining a main discharge gap, and auxiliary electrode means within said vessel for controlling the initiation of a discharge across said main gap, the pressure of said filling and the distance between said cathode and said anode being such that when a potential is impressed between said cathode and anode to sustain a discharge therebetween, the anode is within the Faraday dark space of the discharge and so close to the cathode that no substantial ionization obtains immediately adjacent said anode.

16. A glow discharge device in accordance with claim 15 wherein said gaseous filling is argon at a pressure above substantially 5 millimeters of mercury and less than about 35 millimeters and said distance is less than 0.64 inch.

17. The method of constructing a glow discharge device including a cathode and an anode in a gas-filled enclosing vessel, which comprises impressing between said cathode and anode a potential sufficient to establish a discharge therebetween, and adjusting the distance between said cathode and anode until the anode is in the Faraday dark space of the discharge and at such

region that the discharge is free of oscillatory noise.

18. The method of constructing a glow discharge device including a cathode and an anode in a gas-filled enclosing vessel, which comprises impressing between said cathode and anode a potential sufficient to establish therebetween a discharge of current intensity adequate to utilize all of the effective emissive surface of said cathode, and positioning the anode in the Faraday dark space and at a region thereof at which anode glow does not occur.

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