This invention relates to electric discharge lamps. Electric discharge lamps with hot cathodes have hitherto been constructed in the form of long cylindrical tubes, and in these tubes that portion of the discharge called the "positive column" or body is used as the source of light. For this reason efforts were made to enhance the light intensity of the positive column as much as possible, and numerous measures, for instance the artificial narrowing of the discharge path between the electrodes, were contrived for this purpose.

Under certain circumstances there can also be observed in these known lamps, in the space in the immediate vicinity of the hot cathode, a light phenomenon which, probably in consequence of its slight extent in comparison with the long positive column, is at first but slightly conspicuous, but is sharply distinguished from the positive column not only on account of its different appearance but also owing to the circumstance that its existence and development appear to be closely connected with the phenomena occurring on the hot cathode and especially with the electron emission thereof.

The present invention is based upon the recognition of the fact that this light phenomenon of the "cathode discharge part" is far more suitable for development as an effective source of light than is the positive column, especially if the lamp is to have the usual dimensions and candle power of incandescent lamps. The invention, therefore, proceeds systematically from the endeavour to weaken as far as possible, or completely to suppress, the positive column or the light phenomenon corresponding thereto, and, on the other hand, to bring to the greatest possible development the light phenomenon adjoining the hot cathode and therewith connected.

This object is achieved by means of a sufficiently low gas pressure and slight distance between the electrodes. It has been proved that—subject to the maintaining of certain conditions—the positive column becomes steadily smaller or weaker and in any case less significant as the distance between the electrodes is diminished, but that thereby the light phenomenon of the cathodic discharge part retains its strength or even increases in intensity and extent. A similar effect is achieved by reducing the gas pressure or the density of the gas or by any other means which diminishes the relation of the distance of the electrodes to the mean free path of the electrons in the gas.

In accordance with the aim of the invention, it is desirable, on the one hand, to avoid all those circumstances which favor the development of a positive column and, on the other hand, to ascertain and preserve the conditions necessary effectively to promote the development of the "cathodic" light phenomenon.

Before proceeding to details it must, however, be explained what is meant above and below by "cathodic" discharge parts and "cathodic" light phenomenon. In a physical sense most gas discharges are not uniform phenomena but arise from several parts sharply distinguished from one another as regards their appearance and behavior. Adjoining the cathode there is always a sphere of discharge, which (in many cases consisting of several zones) is closely connected with the phenomena occurring on the cathode and which appears to be associated, so to speak, with the cathode; for this reason it may be called the "cathodic" discharge sphere or "cathodic" discharge part. The close relation of this part of the discharge to the cathode may be seen, for example, from the fact that it slavishly reacts to changes of the position of the cathode, whereas other discharge parts, such as the positive column, remain substantially unaffected by such changes of cathode position. Another criterion is the manner of development of the light phenomenon located in the cathodic discharge parts, and, therefore, designated "cathodic" light phenomenon. When the gas pressure is increased, the light phenomenon is compressed, namely, towards the electron-emitting surface of the cathode, and gains volume from the surface of the cathode outwards, if the gas pressure be reduced. In every way there is a close relation between the electron-emission of the hot cathode—the invention relates exclusively to hot cathodes—and the cathodic light phenomenon, a relation which is expressed, for example, in the circumstance that an increase of the electron emission increases the intensity of the light, and that only such spaces are excited to light as are directly or indirectly subjected to the influence of the electrons emitted. Regarding this reference to a "cathodic" part of the discharge, it should be observed that this part may under certain circumstances also encompass the whole or practically the whole of the discharge or of the lamp, the non-cathodic parts being completely or almost completely suppressed. As already explained, the particular endeavor of the present invention is to produce such extreme cases, so that the cathodic light...
phenomenon may form the principal source of light in the lamp.

In the construction and working of the hot cathode several conditions must be observed, as they are of great importance in the production of the desired cathodic light phenomenon—a circumstance which also indicates the close connection between the cathodic discharge parts and the cathode.

In the first place it should be pointed out that the temperature of the hot cathode should not be chosen too high, presumably on account of its influence upon the temperature of the neighboring cathodic discharge sphere. It has been proved that the desired cathodic light phenomenon, for instance when tungsten is used for the electron emitter of the hot cathode, does not come into being. For this reason the invention is confined to lamps the hot cathodes of which emit abundant electrons even at a relatively low temperature. For this purpose substances should preferably be used which emit a sufficient number of electrons even at 1000° C. or less.

Materials capable of such emission and answering these requirements are, for instance, the oxide compounds of the alkaline earth metals or these latter themselves. The reduction of the emission temperature also promotes the efficiency of the lamp.

Further, it has been found that considerable potential differences between various portions of the emitting hot cathode surface should be avoided, as otherwise it is impossible to achieve durable operation and the formation of a lasting cathodic light phenomenon. If, for instance, a current-carrying incandescent wire, coated with an emissive substance, serves as hot cathode ("directly" heated hot cathode) immediately after starting, the discharge will concentrate in the manner of an arc light upon an individual spot in the incandescent wire, and will instantly evaporate the emissive coating at that spot, in most cases even burning up the filament itself. For this reason only Indirectly heated cathodes are in general applicable to lamps in accordance with the invention, since with indirect heating it is not difficult to keep the emitting surface of the hot cathode at constant potential and more or less uniform temperature. Indirect heating of the cathode from inside has proved particularly advantageous.

The shape of the lamp bulb, especially where it limits the discharge between the electrodes, has in most cases considerable influence upon the coming into being, or the suppression, of the positive column. Narrow waisting of the discharge in the space between the electrodes favors the creation and development of the positive column and at the same time hinders the extending of the cathodic light phenomenon, which is prevented, so to speak, by the positive column from penetrating into the waisted portion of the lamp. Effort is, therefore, made to limit as little as possible the cross-sectional dimensions of the discharge space between the electrodes, i. e. the dimensions at right angles to the discharge path, so that, for example, in the case of a cylindrical bulb with electrodes arranged at the ends thereof, short and wide cylinders are preferable to long and narrow tubes. In any case, waisting of the vessel in the space between the electrodes should as far as possible be avoided, even if such waisting were to be effected at individual points only.

The above-mentioned influences of the shape of the vessel can be relegated to the more general category of the "wall influences," and the more general requirement can be laid down that these influences, insofar as they—which is usually the case—promote the creation of the positive column and, on the other hand, hinder the development of the cathodic discharge parts, should be eliminated as far as possible. It is clear that it is difficult in view of the manifold ways in which the wall influences come into play, and of their dependence in any particular instance upon the shape of the vessel, the size, spacing, and arrangement of the electrodes, as also upon numerous other individual factors, to lay down rules and instructions for the combating of these influences which can be effectively followed in all cases. If, however, the object aimed at, as in the present invention, is to suppress the positive column and to promote the cathodic light phenomenon, it will be perfectly possible in any individual case to ascertain by testing the character of the wall influences, and to counteract an injurious influence in the shape required by the invention by means of a suitable change of one or more of the determining factors in the construction of the lamp.

In most cases, especially in lamps of approximately the size of the usual incandescent lamps, the bringing of the electrodes together in the manner prescribed by the invention will in itself suffice to eliminate injurious wall influences. As a more general directive, it is a useful rule to avoid providing bounding surfaces to the discharge space which face the hot cathode alone (or, in the case of alternating current lamps, one of the hot electrodes only). In accordance with this rule shapes of vessel will be chosen the inner wall of which is turned towards the two electrodes throughout, the bulb-, globe-, and pear-shaped vessels being examples of such shapes. The simple tubular vessel also complies with this rule; this is, however, no longer the case if the ends containing the electrodes be widened out into bulb shape. Experience has proved that in the case of the last-named lamps the positive column comes into being more easily than in similar lamps in which the ends are not widened out into bulb shape.

It is an open question whether the wall influences are due to the formation of static electric charges. Nevertheless, this hypothesis is serviceable from an heuristic point of view. If this theory be applied to the object of the present invention, the shape and size of the wall and the position of the electrodes must be chosen in such a manner that no lasting negative charging of the wall can take place.

In evolving the shape of the lamp bulb care must be taken that the wall be not brought too close to the emitting surface of the hot electrode. Apart from the possibility of the wall becoming heated beyond the permissible limit, the development of the cathodic light phenomenon could also be jeopardized thereby.

In designing a type of lamp in accordance with the present invention it is possible to proceed from a given shape of bulb and, by reducing the distance between the electrodes and diminishing the gas pressure, to ascertain by experiment the dimensions at which the cathodic discharge parts are the principal or even sole source of the light emitted by the lamp. In some cases it is also possible to proceed from a given arrangement of electrodes and, by rightly shaping and dimensioning the bulb and at the same time choosing the
a sufficiently low gas pressure, to suppress the positive column in order to obtain a lamp in which the cathode is not the source of the light emitted by the lamp. This is obtainable by changing only one of the two factors, namely the pressure of the gas and the clearance between the electrodes, to create conditions in which the cathode discharge parts constitute the source of the light emitted by the lamp. This tends to be more particularly the case with small lamps in which any possible spacing of the electrodes is within the permissible limits for the realization of the invention, so that experiment can be confined to the reduction of the gas pressure; in this manner the possibility is provided of manifestly varying the construction and arrangement of the system of electrodes with a view to satisfying other requirements (such as unhampered emission of light, easy and simple mounting of the interior system of the lamp, etc.) without making the alteration of the alternative of one of the two factors, namely gas pressure and electrode spacing, should not suffice for arriving at a lamp in accordance with the invention, it is then possible to change the other factor also, and in general in this way to achieve the desired result rapidly and with certainty; if the special shape of the lamp bulb should still render it difficult to suppress the positive column, this difficulty can then also be combated by suitable modification of the shape of the bulb.

When, by the use of the means of accordance with the invention, a lamp has been obtained in which the emission of light originates exclusively or mainly from the cathode discharge parts, it is possible by means of further steps to bring the cathode light phenomenon to complete development, so that an extremely effective and economical source of light is obtained.

It has been observed—as mentioned above—that when the gas pressure is reduced the cathode light phenomenon is increased in extent, the light phenomenon proceeding from the emitting layer of the cathode surface appearing to expand outwards. The light phenomenon, which is at first confined to a small space bordering on the hot cathode, will, as the gas pressure diminishes, fill up a constantly growing space in the lamp, and extend as far as the electrode acting as anode or even beyond the same, so that this latter lies wholly or partially within the luminous gas, that is to say within the cathode discharge parts; in many cases the expansion of the cathode light phenomenon may proceed so far as to reach the wall of the lamp and thus fill up the whole of the bulb. In my copending application Serial No. 468,884, now Patent 2,213,182, I have described and claimed the specific arrangement whereby the cathode light phenomenon reaches out to the walls to fill the light bulb. In order to obtain a source of light as bright and efficient as possible, the gas pressure is reduced as far as it is possible to do so without incurring the risk of giving rise to special disadvantages. Diminution of the intensity of the light emitted, overheating of the wall and of the inside of the arc-like short-circuiting, and other operating conditions all finally set limits to the extent to which the gas pressure can be reduced. It will be clear that in any particular instance this limit and the most favorable gas pressure will depend substantially upon the lamp design, the arc length and the current density of the discharge current have the same effect as reducing the gas pressure. In general these steps enhance the intensity of the light emitted, and here again the danger of destroying the emissive layer and of overheating the walls of the vessel determines the limit which should not be surpassed. It will be clear that the working values for the emission temperature, current density, gas pressure, and other factors cannot be chosen independently, but must be properly adjusted relatively to each other.

In general, the special construction and arrangement of the electrode acting as anode are immaterial for the creation and development of the cathode light phenomenon, provided, of course, that—for the given gas pressure—the maximum spacing of the electrodes required for the suppression of the positive column be not surpassed, and the anode be not so arranged that injurious wall influences can play an important part. Usually—as already mentioned—the anode will not hinder the expansion of the cathode light phenomenon and may even be enveloped by it; and in respect of this characteristic feature, which also results in several advantages to the lamp in accordance with the invention, the cathode light phenomenon is distinguished from that of the positive column, which always remains confined to the space between the electrodes. If the anode should be enclosed within the cathodic light phenomenon, it must not be so constructed that a considerable gas zone adjoining it is totally screened off by it from the electric field. Such would be the case, for instance, if the anode enveloped the hot cathode like a cage or with the screening effect of an electrostatic cage; in such a case the cathode light phenomenon could not extend into the space outside of the cage.

The endeavor to avoid an excessive screening effect on the part of the anode, and the no less important light-technical requirement, that the light phenomenon be interfered with as little as possible by the anode, call for as small an anode surface as possible in the case of lamps in accordance with the invention operated with direct current or with alternating current rectified by the valve effect of the lamp. The surface of the anode is, therefore, generally chosen no larger and often even much smaller than that of the hot cathode; for instance by the use of a simple wire as anode. The fact that this is possible—without impairing the production of light and the working capacity of the lamp constitutes a further advantage of the invention. Similar advantages are afforded by the above-mentioned possibility of placing the anode in many lamps in any desired position, and therefore also in such a manner as not to impede the light radiation. Alternating current lamps in accordance with the invention, in which the two electrodes are constructed as hot cathodes and function in consecutive half cycles as hot cathode and anode alternately, are especially favorable, in that in the light radiation is unhampered, since at a sufficiently high frequency alternating current changes when the eye sees simultaneously and uninterruptedly the light phenomenon occurring in both half cycles, so that to each electrode there appears to be connected a cathode light phenomenon, which in
most cases even envelopes or encloses the electrode, provided the hot electrode be so formed that it emits electrons in all directions. In this way light disturbing elements inside the lamp are almost completely avoided. In the case of a sufficiently short distance between the electrodes, the light phenomena associated with the two hot electrodes occupy partly (but in chrono-
logico-succession) the same space, the eye gaining the impression that the two light phenomena have united to form a single one. It is of advantage to make the two hot electrodes of the same alternating current lamp of the same size and also otherwise similar. In my copending application Serial No. 497,025, now Patent 2,213,183, I have described and claimed the specific arrange-
ment whereby the two cadiotic light phenomena unite to all intents and purposes to give the effect of a single cadiotic light phenomenon.

The invention not only improves electric rare gas lamps in regard to their luminosity by making an extremely effectively radiating but up to the present not appreciated and in any case not exploited portion of the luminescent discharge into the source proper of light, but also constitutes progress in regard to the size and current dependency of the voltage employed, and in regard to uniform heating of the hot cathode. Efforts have long been made to reduce as far as possible the operating and discharge voltage of rare gas lamps, and more particularly in this direction was the hot cathode introduced in place of the cold cathode. But even with hot cathodes success was not achieved in obtaining discharge voltages (voltage drops) substantially below 50 volts.

In conjunction with the present invention it was recognized that the low discharge voltage achieved up to the present in rare gas lamps with a hot cathode by no means represents the lowest possible limit, and that it is only due to the particular shape of the lamps hitherto known (for instance, in the form of long tubes widened out at the ends carrying the electrodes) that the theoretical minimum of discharge voltage could not in practice be employed. It has been found that in most cases the measures according to the invention serving to suppress the positive column, and particularly the reduction of the gas pressure and of the electrode spacing, cause a reduction of the discharge voltage, so that finally—corresponding to the practical disappearance of the column—a minimum value for the voltage is reached which upon further reduction of the gas pressure and of the electrode clearance cannot be reduced any further. This low voltage constitutes an important characteristic of a class of lamps according to the invention, and the presence of this feature can be recognized by the fact that in such lamps a further reduction of the gas pressure and of the electrode spacing—other conditions remaining unaltered—cause no further diminution of the voltage drop between the electrodes. In every individual case it can, therefore, be ascertained by means of one or more trials whether a lamp possesses the "minimum voltage" according to the invention. The shape of the vessel may also, in consequence of the above-mentioned "wall influence" interfere with the obtaining of the minimum voltage in the above sense; these obstacles may, however, be overcome by the use of the measures proposed for the elimination of the wall influence.

It will be clear that the numerical value for the "minimum voltage" depends upon the nature of the gas filling. In lamps the filling of which contains neon it is about 16 volts, but in any case less than 25 volts. In such lamps the gas pressure and the electrode spacing will therefore be diminished until the voltage drop values of the above-mentioned order are obtained.

The reduction of the gas pressure and of the electrode spacing and other measures to be taken in accordance with the invention also improve the volt-ampere characteristics of the tube by decreasing it, so that a class of lamps is finally arrived at in which the voltage drop of the discharge remains practically constant within a considerable range of current intensity. This voltage stability is perhaps to be explained by the fact that the measures according to the invention eliminate all those causes of loss (positive column, wall influence, and the like) the voltage consumption of which depends upon the density or intensity of the current. The stability of the voltage drop of the discharge, namely of an important operating characteristic, is likewise achieved in the operation of the lamp, since fluctuations of the operating voltage cannot influence the discharge voltage.

The fact that the discharge voltage is dependent on the discharge current, however, also renders possible an improvement in the heating of the hot electrodes. It is clear that a constant heating of the hot cathode or hot electrodes is of great importance in the operation and utility of the lamp on account of the electron emission depending thereupon. While the heating current in the known rare gas lamps with indirectly heated hot cathode either depends upon an operation factor subject to unavoidable fluctuations, such as ordinary line voltages, or is supplied from a special source of current, it may, according to the invention, be automatically kept at practically constant value, after the starting of the lamp has taken place, irrespective of the intensity of the discharge current. This is achieved by connecting in parallel (shunt) with the discharge path the heating circuit or heating wire of the hot electrode or electrodes in a lamp the voltage drop of which is constant within the operating range or a rather large range of the current intensity, namely so that a constant value of the heating current corresponds to the constant voltage drop of the discharge. In consequence of this fact, the separate heating of the hot electrode or electrodes will quite automatically assume a constant value within that range of the discharge current in which the discharge voltage is constant, and, as this value is equivalent to the current necessary for starting, the further economic advantage is thereby gained that at all intensities of the discharge current the lamp takes up and consumes in separate heating only the amount necessary for starting. After the starting of the lamp has been effected, an increase of the hot electrode temperature is only caused by the discharge itself and then in a gradually ascending and easily regulated manner.

On account of the above-mentioned wiring, burning out of the heating wire of the hot electrode or electrodes may therefore be effectively prevented in the case of fluctuations of the ordinary line voltage, since the gas space acts, so to speak, as a safety-valve against voltage surges: on this account the heating wire may be dimensioned closely in relation to the discharge voltage of the lamp.

The values for the gas pressure and for the electrode spacing required for the carrying out
of the invention will be different for different constructions of lamps, and will depend upon the kind of gas filling, the shape of the bulb, the size and nature of the electrodes, and other factors, so that it is hardly possible to lay down a general rule valid in all cases, and one that will yield theoretical values. A further matter for consideration is the predominant point of view from which the designing of the lamp is governed, that is to say whether the purpose is chiefly to suppress the positive column or to arrive at the minimum discharge voltage in the present instance.

On the other hand, there may also be lamps the gas pressure and electrode spacing of which correspond to these given rules, and yet, in consequence of special formation of the vessel and of the existence of considerable "wall influences," do not show, or show only incompletely, the cathode light phenomenon, or have too high a discharge voltage, or are dependent upon the current.

As a general rule, it will be advisable to choose the product (P) of gas pressure in mm. of mercury column and the space, in millimeters, between the electrodes so as to be not higher than 100; though in most cases favorable values of P lie between 10 and 40, and for preference at 20.

In this connection it should, however, be remarked that in the case of extreme values of the electrode spacing (over 30 cm, below 5 mm.) P loses its significance as a characteristic numerical value. In the case of small lamps, the bulb of which approximates that of the usual incandescent lamp in size and shape, the gas pressure will be chosen at the first approximation below 10 mm. and preferably between 1 and 5 mm., and the electrode spacing will not be made too great, for instance less than 50 mm., but the latter can also be reduced as low as 2 mm.; a short "electrode spacing" is particularly advantageous with alternating current lamps with two hot electrodes. However, with these small lamps any electrode spacing often suffices, so that only the range of the necessary gas pressure remains to be determined.

Any rare gas or rare gas mixture is suitable as a gas filling for the lamp, and metal vapor, particularly mercury vapor, can also be added to the filling. The cathodic light phenomenon becomes especially intensive and suitable for practical use as a source of light, if the gas filling contains neon alone or neon mixed with other gases, containing lamps constructed in accordance with the invention prove the qualification of the cathodic light phenomenon to be used as a practical source of light.

The cathodic light phenomenon consists in most cases, especially with gas filings containing several gases or vapors, but often also with pure gases, of two or more zones of different light intensity and sometimes of different colors, whereby the zone adjoining the hot cathode (hot electrode) always possesses the greatest light intensity, and constitutes the most efficient portion of the phenomenon and tends to give the impression that it corresponds to the immediate sphere of action of the electrons emitted by the hot cathode, and this conception is supported not only by its dependence in extent and intensity upon the gas pressure and electron emission, but also by the appearance of the inner zone in that region adjoining the non-emitting portions of the hot cathode; the more dimly luminous outer zone may perhaps be attributable to some secondary effects of the electron emission from the hot cathode. It must, however, be stressed that these views of the individual zones are only hypothetic conceptions, which perhaps possess euristic value; they might, however, equally well be replaced by explanations of an entirely different kind.

The lamps according to the invention can be operated with either direct or alternating current. In the former case it suffices to develop the cathode as an indirectly heated hot cathode; nevertheless, lamps with two or more hot electrodes are also suitable for operation with direct current. Lamps operated with alternating current can most advantageously be provided, for the reasons given above, with two similar hot electrodes, but, owing to the rectifying effect, lamps with a single hot electrode can be made to light with alternating current, but in this case the frequency of the current must be so high that any dazzling flickering of the light may be avoided. Naturally, under certain circumstances, auxiliary electrodes can also be arranged in the lamps.

The drawing shows examples of forms of lamps in accordance with the invention; it must, however, be understood that only a few individual cases have been selected from the great number of possible forms of construction. In Fig. 1 there is represented a direct current lamp, and in Fig. 2 an alternating current lamp, both with globe-shaped vessels; these figures also show the wiring serving to keep the separate heating current constant. In Fig. 3 a lamp is illustrated with cylinder-shaped vessel, while Fig. 4 shows a tubular lamp, in order to explain the influence of the narrowing of the vessel between the electrodes; the lamps in Figs. 3 and 4 possess two hot electrodes and are, therefore, designed particularly for operation with alternating current. Fig. 5 illustrates certain electrical starting characteristics of the lamps.

The indirectly heated hot electrodes (in Fig. 1 the hot cathode) consists substantially of a little base tube (for instance made of nickel, molybdenum, or tungsten) with heating wire 2 (for instance a tungsten wire) within it and on the outside of it an electron-emitting coating (for instance barium oxide). Each little nickel tube is connected with the respective terminal of the direct- or alternating-current source, and this is most simply done by means of a conductive connection between the little tube and the leading-in wire for the heating wire 2; the heating circuit and the discharge circuit may, however, also be completely separate. In Fig. 1 and Fig. 2 the heating circuit is in parallel to the gas discharge path, and, since the lamps of these figures possess the characteristics indicated in Fig. 5, which shows the electrical starting char-
characteristics whereby the discharge voltage beginning from the starting point Z runs independently of the current (parallel with the axis of abscissae), the current passing through the heating wire will always retain the same value for different values of the discharge current. In consequence of this fact, even at relatively high discharge currents the lamp will only consume the extra heat necessary for starting. The interior wiring of the heating circuit (which can embrace one or both electrodes) can be of any kind, and any desired type of resistance may also be included in the heating circuit. All lamps are incompletely coated with an electron-emitting layer, it is enclosed by the cathodic light phenomenon the innermost zone of which is indicated by the dotted outline 4, so that the electrode in no way interferes with the light radiation. Since the anode 3 in Fig. 1 takes the form of a plain wire of small superficial area, it, too, will scarcely obstruct the path of the light rays. In the case of the lamps shown in Figs. 1 and 2, the more dimly luminous outer zone of the cathodic light phenomenon will extend in most cases outwards to the outer edge of the latter be of unusually large dimensions; in short cylindrical lamps also, of the type shown in Fig. 3, the cathodic light phenomenon may in some cases occupy the entire bulb. In lamps of the other type shown in Fig. 2, the bulb as a whole will not be too large and any electrode spacing is admissible, and it only becomes necessary to determine the range of gas pressure at which the cathodic light phenomenon in the sense of the invention occurs. Nevertheless, short electrode spacing is preferable; in the case of lamps of the type shown in Fig. 2, the above-mentioned fusion into a single light phenomenon is thereby promoted. As can also be seen from Fig. 5, the discharge voltage will in most cases be about 16 volts, provided the gas filling contains neon. In lamps constructed in the manner shown in Fig. 3 the electrode spacing must also be taken into consideration, since beyond a certain spacing, any gas pressure is sufficient to give rise to the formation of the positive column. In Fig. 3 the positive column has not damped; the latter is of a weakly developed column. As the electrode spacing is increased, the intensity and extent of the column grow until the latter becomes the predominant light phenomenon of the lamp, after which the lamp can no longer be regarded as being within the scope of the present invention. This occurs much sooner (that is to say at even shorter electrode spacing) if the lamp shown in Fig. 4 be narrowed into tubular shape at its middle portion, since the positive column can form more easily in this narrowed middle portion. In such a lamp the wall influences, especially about where the middle portion joins the extended ends, also play an important part. As a matter of fact, the wall portions form a face only one of the two hot electrodes, while, on the other hand, in the lamps shown in the other figures all portions of the wall always face both electrodes. By extending the middle portion into the vessel shape of Fig. 3 the injurious wall influences can be eliminated. The discharge voltage with neon filling is, in lamps of the type shown in Fig. 3, about 25 volts, whereas in Fig. 4, the discharge voltage is still higher and, especially if a strong positive column appears, exceeds 100 volts.

In addition to the above-mentioned numerous advantages of lamps according to the invention, there is the further advantage of self-starting when the discharge voltage is reached, whereby any special starting device or measure becomes superfluous. This may also be seen from Fig. 5, which shows, for a lamp as shown in Fig. 2, the dependence of the main voltage (operating voltage) E of the lamp upon current I passing into the lamp. The broken line portion of the characteristic shows the voltage rise up to starting (Z), if I is continuously increased. The solid line portion is identical with the heating current of the heating circuit. When the discharge voltage V is reached (and the hot cathode is sufficiently hot), the lamp starts, whereby with further increase of the operating current (portion of the characteristic shown in unbroken lines) the discharge voltage and the heating current remain stable, and only the discharge current of the gas path increases correspondingly.

Data for a lamp of the type shown in Fig. 2 are as follows: electrode spacing 7.25 mm.; gas filling—99.5% neon and 0.5% helium; gas pressure—about 2 mm.; bulb diameter 60 mm.; length of hot electrode 20 mm.; diameter of the hot electrode 2.2 mm.; discharge voltage—about 16 volts and Fig. 2, if the bulb be not too large any electrode spacing is admissible, and it only becomes necessary to determine the range of gas pressure at which the cathodic light phenomenon in the sense of the invention occurs. Nevertheless, short electrode spacing is preferable; in the case of lamps of the type shown in Fig. 2, the above-mentioned fusion into a single light phenomenon is thereby promoted. As can also be seen from Fig. 5, the discharge voltage will in most cases be about 16 volts, provided the gas filling contains neon. In lamps constructed in the manner shown in Fig. 3 the electrode spacing must also be taken into consideration, since beyond a certain spacing, any gas pressure is sufficient to give rise to the formation of the positive column. In Fig. 3 the positive column has not damped; the latter is of a weakly developed column. As the electrode spacing is increased, the intensity and extent of the column grow until the latter becomes the predominant light phenomenon of the lamp, after which the lamp can no longer be regarded as being within the scope of the present invention. This occurs much sooner (that is to say at even shorter electrode spacing) if the lamp shown in Fig. 4 be narrowed into tubular shape at its middle portion, since the positive column can form more easily in this narrowed middle portion. In such a lamp the wall influences, especially about where the middle portion joins the extended ends, also play an important part. As a matter of fact, the wall portions form a face only one of the two hot electrodes, while, on the other hand, in the lamps shown in the other figures all portions of the wall always face both electrodes. By extending the middle portion into the vessel shape of Fig. 3 the injurious wall influences can be eliminated. The discharge voltage with neon filling is, in lamps of the type shown in Fig. 3, about 25 volts, whereas in Fig. 4, the discharge voltage is still higher and, especially if a strong positive column appears, exceeds 100 volts.

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In addition to the above-mentioned numerous advantages of lamps according to the invention, there is the further advantage of self-starting when the discharge voltage is reached, whereby any special starting device or measure becomes superfluous. This may also be seen from Fig. 5, which shows, for a lamp as shown in Fig. 2, the dependence of the main voltage (operating voltage) E of the lamp upon current I passing into the lamp. The broken line portion of the characteristic shows the voltage rise up to starting (Z), if I is continuously increased. The solid line portion is identical with the heating current of the heating circuit. When the discharge voltage V is reached (and the hot cathode is sufficiently hot), the lamp starts, whereby with further increase of the operating current (portion of the characteristic shown in unbroken lines) the discharge voltage and the heating current remain stable, and only the discharge current of the gas path increases correspondingly.

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a merably below 1000° C., the electrodes being spaced so near one another, the dimensions of the discharge space between them being sufficiently large, and free from obstructions and the pressure of the gas being so chosen with respect to said spacing that the discharge is restricted to a cathodic glow and the positive column is eliminated entirely.

8. An electric discharge lamp as defined in claim 1, wherein the monatomic gas is neon.

9. An electric discharge lamp as defined in claim 1, wherein the monatomic gas is neon and which contains also mercury vapor.

10. An electric discharge lamp as defined in claim 1, wherein no boundary surface of the containing vessel faces a hot cathode alone.

11. An electric discharge lamp as defined in claim 1, having a containing vessel which is substantially spherical.

12. An electric discharge lamp as defined in claim 1, having a containing vessel which is substantially pear-shaped.

13. An electric discharge lamp as defined in claim 1, having a containing vessel which is substantially cylindrical.

14. An electric discharge lamp as defined in claim 1, wherein the gas pressure and electrode clearance are selected so small that further reduction of either or both of these factors will not produce any further decrease in voltage drop of the discharge between the electrodes.

15. An electric discharge lamp as defined in claim 1, wherein a voltage drop of the discharge lies between 16 and 30 volts.

16. An electric discharge lamp as defined in claim 1, wherein the gas pressure and electrode spacing are selected so small that the voltage drop of the discharge within a relatively large range of current values is approximately constant.

17. An electric discharge lamp as defined in claim 1, wherein a containing vessel so constructed that it causes no increase or current dependence of the voltage drop of the discharge due to wall charges and the like on said vessel.

18. An electric discharge lamp as defined in claim 1, particularly for use with direct current, and which has an anode of smaller area than the hot cathode.

19. An electric discharge lamp as defined in claim 1, wherein the spacing between the electrodes is chosen so small that the electrode which is serving at any time as anode lies at least partly within parts of the cathodic discharge.

20. An electric discharge lamp as defined in claim 1, and particularly adapted for use with alternating current, wherein there are provided two hot electrodes of substantially similar size and construction.

21. An electric discharge lamp as defined in claim 1, wherein the product of the gas pressure measured in millimeters of mercury and the electrode spacing measured in millimeters lies between 10 and 40.

22. An electric discharge lamp as defined in claim 1, wherein the product of the gas pressure measured in millimeters of mercury and the electrode spacing measured in millimeters is preferably approximately 20.

23. An electric illuminating lamp comprising a bulb, two closely spaced electrodes therein at least one of which is capable of emitting electrons freely when heated, a resistance member capable of heating said electrode to its electron emitting temperature, one end of which resistance member is connected to the electron emitting electrode and the other end thereof to the other electrode to permit the application of a potential between said electrodes, and a rare gas filling for said lamp, the pressure of said gas filling being such that at the electron emitting temperature of said electrode and at the operating potential of the lamp a luminous gaseous discharge arises in the form of expanded cathodic light.

24. An electric illuminating lamp for alternating current, comprising a bulb, a rare gas filling, two spaced electrodes at least one of which is capable of emitting electrons freely when heated, and a resistance member for continuously and indirectly heating said electrode to its electron emitting temperature, one end of said resistance member being permanently connected to the electron emitting electrode and the other end thereof being permanently connected to the other electrode to permit the application of a potential between said electrodes, the density of the discharge current at any given pressure of said gas filling being such that a luminous gaseous discharge arises in the form of expanded cathodic light.

25. An electric illuminating lamp for alternating current comprising a bulb, two co-operating electrodes therein each of which is capable of emitting electrons freely at relatively low temperature, a resistance heater for continuously and indirectly heating said electrode, one end of each resistance heater being permanently connected to its electrode, a low resistance bridge permanently connecting the other ends of said resistance heaters, lamp terminals permitting electric current to be supplied to said heating member and a potential to be applied between the electrodes, and a rare gas filling for said lamp, the pressure of said filling and the electrode separation being such that at the electron emitting temperature of said electrodes and with an inter-electrode potential approximately of the order of the ionizing potential of the rare gas no appreciable positive column can arise.

26. An electric discharge lamp which provides useful illumination by expanded cathodic light which comprises a monatomic gas filling at a pressure of less than 10 millimeters of mercury and having at least one indirectly heated electron emissive electrode, the density of the discharge at any given pressure of said gas filling being such that a luminous gaseous discharge arises in the form of expanded cathodic light.

27. An electric luminous gaseous discharge lamp comprising, an envelope having an ionizable medium therein, co-operating metal electrodes at least one of which is capable of emitting electrons freely when heated to a relatively low tem-
temperature, a resistance heater for continuously and indirectly heating said electrode during the operation of the lamp, a lead-in wire for each electrode, and permanent connections within the envelope between one end of said heater and the electron emitting electrode such that the gaseous discharge path is electrically in parallel with the resistance heater.

25. An electric luminous gaseous discharge lamp comprising, an envelope having an ionizable medium therein, a metal anode, another metal electrode which is capable of emitting electrons freely when heated to a relatively low temperature, a resistance heater for continuously and indirectly heating said electrode during the operation of the lamp, and permanent connections within the envelope between one end of said heater and the emissive electrode on the one hand and between the other end of said heater and the anode on the other hand.

26. An electric luminous gaseous discharge lamp comprising, an envelope having an ionizable medium therein, a metal anode, another metal electrode which is capable of emitting electrons freely when heated to a relatively low temperature, a resistance heater for continuously and indirectly heating said electrode during the operation of the lamp, and permanent connections within the envelope between one end of said heater and the emissive electrode on the one hand and between the other end of said heater and the anode on the other hand.

27. An electric luminous gaseous discharge lamp comprising, an envelope having an ionizable medium therein, two similar co-operating metal electrodes each of which is capable of emitting electrons freely when heated to a relatively low temperature, a resistance heater for continuously and indirectly heating each electrode during the operation of the lamp, a permanent connection within the envelope between each electrode and one end of its heater and a low resistance bridge connecting the other ends of said heaters.

28. In a gaseous conduction lamp, two resistance heater elements in series, and electrodes for a gaseous arc discharge surrounding said elements and connected thereto, the potential difference between them necessary for such a discharge being effected by the potential drop across the two resistance heater elements.

29. A gaseous discharge device comprising an enclosing envelope having an ionizable medium therein, a plurality of spaced apart electrodes of the indirectly heated type within said envelope and separate means for heating each of the said electrodes, said means being connected in series and connected to the electrodes.

30. A self-regulating glow discharge device comprising a bulb having a gaseous filling, an electrical circuit including an electrode and a thermionically active cathode, a heater element for said cathode, a source of electrical energy to supply a given amount of current for said circuit to heat said element to render said cathode electron emitting, said cathode being so arranged with respect to said circuit as to bypass a portion of said current supply through said cathode to said electrode to cause a glow discharge therebetween, whereby the amount of current passing through said heater element is reduced and the operation of the device controlled.

31. A device comprising a sealed envelope having therein an ionizable medium, a plurality of heater elements disposed in spaced parallel relation, means connecting said heater elements in series and a thermionically active body adjacent to each of said heater elements to be heated thereby with said heater and said heater elements being electrically connected to said body with said heater elements.

32. In a glow discharge device, an hermetically sealed envelope, an ionizable medium therein, a plurality of spaced apart heater elements within said envelope and connected in series, a plurality of electrodes one for each heater element and heated thereby, each of said electrodes being electrically connected to its heater element whereby when alternating current is passed through said heater elements said heater elements will become heated and in turn heat said electrodes to electron emitting temperatures thus causing a portion of the current to flow between said electrodes and ionize the said medium, an increase in said electrode current causing a decrease in said heater current and anode current will be caused to diminish and vice versa.

33. A discharge device comprising a bulb having a gaseous filling, a press, conductive support wires extending from said press, heater elements disposed in spaced relation and each having an end secured to a support wire and having their other ends connected together, tubular members having external coatings of thermionically active material disposed about said heater elements and electrical connections between said supports and said members.

34. A gaseous discharge device, comprising an enclosing envelope having an ionizable medium therein, a plurality of spaced apart electrodes of the indirectly heated type within said envelope and including means for continuously supplying heat to the electrodes during operation of the device, said means being connected in series and connected to the electrodes.

35. A gaseous discharge device comprising an enclosing envelope having an ionizable medium therein, a plurality of spaced apart electrodes within said envelope one of which is a cathode of the indirectly heated type including means for continuously supplying heat to said cathode during the operation of the device, said means being connected in shunt with the path between one of said electrodes and said cathode.

36. In a gaseous conduction or similar lamp, an envelope, resistance heater means connected in series, spaced electrodes of the indirectly heated type adjacent to said heated means so as to be continuously heated thereby during operation and adapted to have a potential difference applied thereto less than the ionization voltage of the gas used, a connection between one electrode and one part of the heater means, a connection between the other electrode and another part of the heater means, and an ionizable medium within the envelope at a pressure to produce a glow discharge between the electrodes.

37. A gaseous discharge device, comprising an enclosing envelope having an ionizable medium therein, a plurality of spaced apart tubular electrodes of the indirectly heated type within said envelope the outer surfaces of which are provided with electron emitting material, and means extending axially through said electrodes for continuously supplying heat to said electrodes during the operation of the device, said means being connected in series and connected to the electrodes.
38. In an electric discharge lamp, an envelope containing an ionizable gas, two spaced apart resistance heater elements within said envelope, a pair of thermionically active electrodes within said envelope each of which comprises a tubular member surrounding one of said heater elements and adapted to be continuously heated by the latter during the operation of the lamp, a lead-in wire for each electrode, one of the ends of each of said heater elements being connected to their respective electrodes at one of the ends of said electrodes, and means within the envelope for connecting the other ends of the heater elements.

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