I. LANGMUIR.

INCANDESCENT ELECTRIC LAMP.

APPLICATION FILED APR. 19, 1913.

1,180,159.

Patented Apr. 18, 1916.

2 SHEETS—SHEET 1.

Fig. 1.

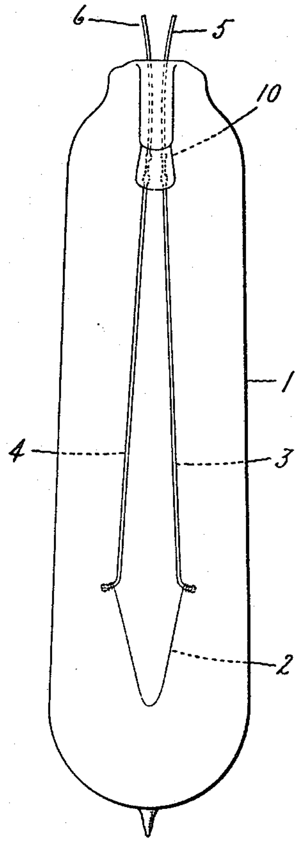
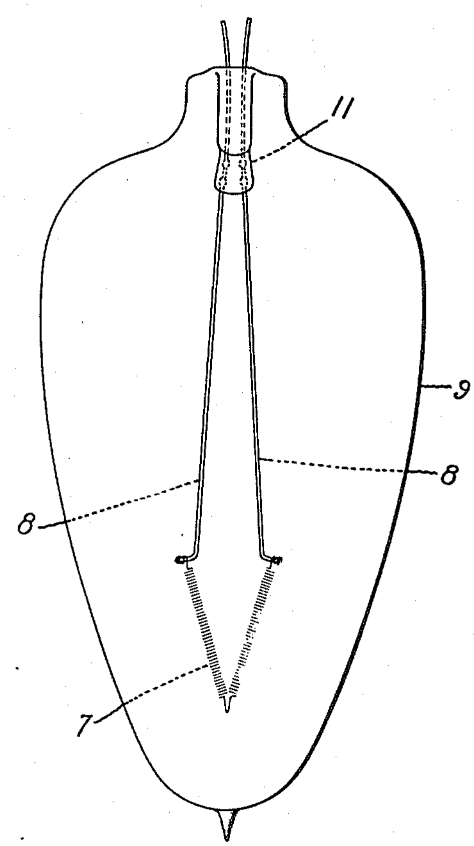


Fig. 2.



Witnesses:

George H. Tilden

J. Ellis Glen

Inventor:

Irving Langmuir,

by Albert G. Davis

His Attorney.

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2 SHEETS—SHEET 2.

Fig. 3.

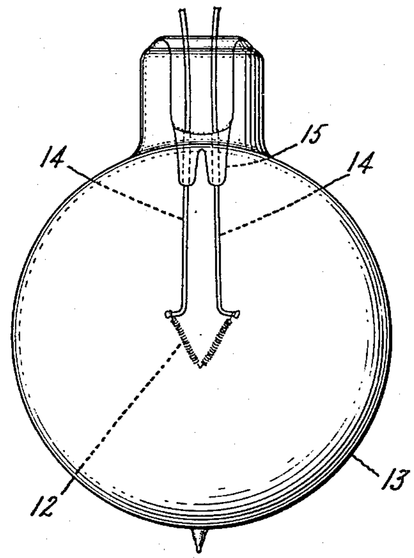


Fig. 4.

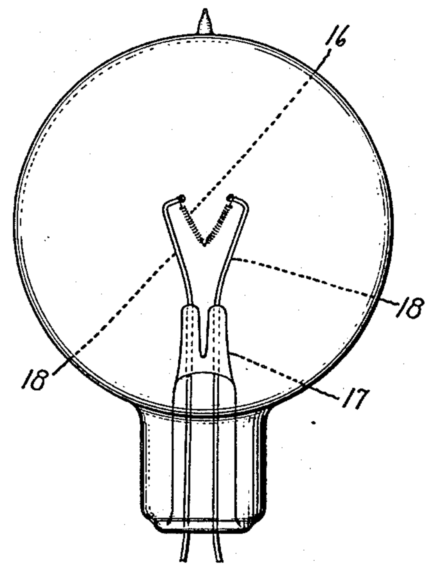
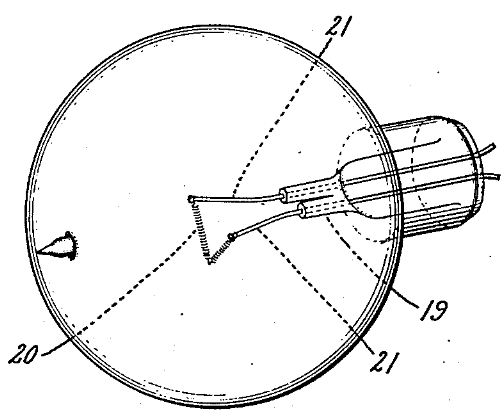


Fig. 5.



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by Albert G. Davis
His Attorney.

UNITED STATES PATENT OFFICE.

IRVING LANGMUIR, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

INCANDESCENT ELECTRIC LAMP.

1,180,159. Specification of Letters Patent. **Patented Apr. 18, 1916.**

Application filed April 19, 1913. Serial No. 762,327.

To all whom it may concern:

Be it known that I, IRVING LANGMUIR, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Incandescent Electric Lamps, of which the following is a specification.

My present invention relates to improvements in incandescent electric lamps whereby it is possible to produce a lamp capable of operating at extraordinarily high efficiency and giving a light of marked increase in intrinsic brightness and whiteness, as will be more fully hereinafter set forth.

In the drawings attached to this specification, Figure 1 is a view of a lamp embodying my invention, while Figs. 2, 3, 4 and 5 show modifications within the scope of my invention.

I will now proceed to describe in detail the lamp shown in Fig. 1, which represents one particular type of lamp embodying my invention.

1 is the lamp bulb, which is decidedly elongated; 2 is a filament of tungsten which may be constructed by any of the now well-known squirting or drawing processes. In this case the filament is about 10 mils in diameter and about three inches long. The filament is located near the bottom of the bulb and is supported by heavy, stiff, wrought tungsten wires 3, 4, connected through conductors 5 and 6 with the external terminals. The lamp bulb is filled with nitrogen carefully purified and free from water-vapor, admitted at a pressure which may be as low as say 50 mm. but which to advantage may be atmospheric when the lamp is cool. The bulb is finally sealed in the usual manner.

In the manufacture of the lamp I dry the gas by carrying it a number of times over phosphorous pentoxid, and further I thoroughly dry the bulb of the lamp and free it from adhering gases and water vapor by exhausting for a long time while it is heated in a suitable oven to a temperature as high as can practically be realized without danger of unduly softening the glass, and do not admit the dry nitrogen until I have in this way removed from the glass as far as possible all traces of water vapor.

The particular lamp shown is adapted to operate at a current of about 8 amperes with an efficiency of about .7 to .8 watts per candle. At this efficiency the lamp has substantially the commercial useful life of standard lamps on the market at the present time, the drawn-wire tungsten lamps, which with a corresponding life have an efficiency of about 1 to $1\frac{1}{4}$ watts per candle.

The efficiency of an incandescent lamp of a given type and construction is in general directly related to its useful life, that is to say, a lamp which will operate at $1\frac{1}{4}$ watts per candle for 1,000 hours useful life can be run at one watt per candle by simply increasing the voltage to which it is subjected, but the useful life will be much shortened, and the same lamp set up at .5 watts per candle will be blackened and destroyed in a few minutes.

It is not new in the art to use an incandescent lamp filament of tungsten, as such filaments are well known and in common use on a large scale. It has been suggested in the past to introduce into a lamp bulb a neutral atmosphere at a fairly high pressure, but I am not aware that any such lamps have ever been used commercially or have been technically successful.

It was at one time proposed to introduce nitrogen into the bulb of a lamp having a carbon filament, and, in order to reduce the convection losses, that the filament should be reduced to "a smaller cross section than usual heretofore." The lamp was a failure for reasons which, in the light of the work which I have done, can readily be pointed out. In the first place, as will appear more fully hereafter, the reduction of the cross section of the filament was a step decidedly in the wrong direction, but also very serious is the chemical action between the nitrogen and the carbon of the filament, which at the temperature of incandescence react on each other to form cyanogen, and ultimately para-cyanogen. This action not only obscures the bulb by a deposit of a brown powder of para-cyanogen, but also destroys the filament. It was also proposed to use cyanogen in place of nitrogen, but this combination also is inoperative since the cyanogen decomposes and deposits carbon on the filament, so that the size of the filament continually increases and its resistance continually decreases, and if the lamp be placed in multiple across the mains so that it is supplied with constant potential, the action is a cumulative one, the lamp "runs away," that is to say, the filament grows in size and temperature until in a few minutes it is destroyed, while if on the other hand it is operated in series on a constant current circuit, its reduced resistance reduces its temperature and its efficiency is lost.

My experience has shown that it is necessary that certain relations exist between the atmosphere of the lamp and the material of the filament. The combination which I have found to be most suitable is the one above described. Tungsten possesses a great advantage over carbon which renders it highly suitable for use in my improved lamp, in that it has not only a high melting point but also a very low vapor pressure at high temperatures. The light emission from a lamp is in proportion to the eleventh power of the absolute temperature, so that a very slight increase of temperature above that normally used in incandescent lamps brings about a very considerable increase in efficiency. This increase is sufficiently great in lamps constructed in accordance with my invention to produce the striking results above described, in spite of the fact that a certain amount of heat is wasted by convection; but carbon in an atmosphere of nitrogen or cyanogen, irrespective of the vital difficulties, above mentioned, has the property of slowly vaporizing at temperatures corresponding to three watts per candle, and a very slight increase of temperature causes a considerable increase in the rate of vaporization; so that a carbon lamp operated either in a vacuum or in the manner described by Edison becomes blackened in a few minutes if the efficiency be pushed even to two watts per candle. Moreover, with an efficiency of two watts per candle the life of a carbon filament up to the point of burn out is very short and when operated in nitrogen is very much shorter than when operated in a vacuum.

One important feature of my invention consists in so correlating the filament material with the atmosphere that the atmosphere reduces the tendency of the material to vaporize, and makes it possible to operate commercially at higher efficiencies than can be realized with the same material in a vacuum.

Nitrogen does not attack the tungsten filament, even at the high temperatures mentioned, though it may react on tungsten vapor in the lamp, with the formation of nitrid of tungsten, a material which is less opaque than tungsten. In addition nitrogen is peculiarly suitable as an atmosphere because of the fact that it has a low heat conductivity.

The losses from the filament are of three sorts: first, the direct radiation; second, the conduction through the atmosphere in the bulb; and third, convection. Direct radiation of energy from the filament is desirable, since it is this radiation, or a portion of it, which constitutes the light. The other two losses are harmful and should be minimized as far as possible; in commercial practice they have been reduced to the lowest limit by the use of a very high vacuum.

In place of nitrogen I may use various other gases or vapors, provided that they are properly correlated to the material of the filaments. For example, I may use with a tungsten filament, which filament I have heretofore found to be the best suited to my invention, an atmosphere consisting of argon, or mercury vapor, or other gaseous filling having sufficiently poor heat conductivity and satisfying the other requirements herein indicated. Carbon monoxid may also be used as an atmosphere in the lamp but is not as advantageous as those already mentioned. Hydrogen, however, is distinctly unsuitable because it has good heat conductivity and because it appears to dissociate at the high temperatures at which the filament of my improved lamp must be run, the temperatures being in excess of that of a tungsten filament when operating in a vacuum at an efficiency of one watt per candle. The pressure of the atmosphere in the bulb should be relatively high. I obtain good results for example with a pressure (measured when the lamp is cold) of 300 millimeters of mercury, or as low as 50 millimeters, but higher pressures are preferable, and indeed I usually employ pressures of about one atmosphere. The pressure should not however be so high as to involve any danger of destroying the bulb when the filament is heated. Not only do these high pressures, when utilized in accordance with my invention, reduce the tendency of the filament to vaporize or waste away, but the convection currents set up in the gas surrounding the filament serve to convey away from the vicinity of the filament any vapor which may be emitted. By properly proportioning and designing the parts the material constituting this vapor may be deposited at portions of the lamp where it is not objectionable. For example, in the lamp shown in Fig. 1 the upper portion of the lamp bulb acts as such depositing chamber, while the lower portion remains clear. The depositing action is different than in a vacuum lamp for in the latter case the depositing area in the bulb and the light emitting area largely correspond.

With the ordinary incandescent lamp a very minute emission from the filament will blacken the bulb and seriously reduce the total efficiency, but in lamps constructed in accordance with this feature of my invention the life of the lamp is not so limited, and a very considerable loss of material from the filament can take place. From this point of view it is desirable to operate with filaments of large diameter. But there are other reasons why the diameter of the filament has an important bearing on my invention. I have already spoken of the loss of energy by convection and conduction; I have found that within moderate limits these losses are approximately independent of the size of the filament; that is to say as between a filament 10 mils in diameter and a filament 3 mils in diameter there is very little difference in the magnitude of the conduction and convection losses, but the surface areas of the two filaments are in the ratio of ten to three, and as the light emission at a given temperature is proportional to the surface, the 10-mil filament will radiate more than three times as much light as the three-mil filament, and it is this fact, in combination with the reduced vaporization obtained by suitable choice of filament and atmosphere, and the other features of invention herein described, which enables me to attain the efficiency above indicated.

In a lamp made in accordance with my invention, with a 10-mil filament operating at an efficiency of .52 watts per candle, I find that the filament is operating at a temperature which, if the filament were in vacuum, would correspond to an efficiency of 0.37 watts per candle; the difference of 0.15 watts represents the convection and conduction losses. Of course if an attempt be made to operate an ordinary tungsten filament incandescent lamp at any such efficiency as 0.37 or even 0.52 it rapidly blackens and is destroyed. By employing filaments of still larger diameter, and especially if they be concentrated by coiling or otherwise, the efficiency may be still further raised. Thus I have caused lamps to be constructed in accordance with my invention having coiled or helically-wound filaments of tungsten wire of 20 mils in diameter and operating with a current in the neighborhood of 20 amperes. The candle power was comparable to that of an arc lamp and the efficiency was about .4 of a watt per candle. Owing to the large size of this lighting unit the bulb was made very large to avoid overheating.

An incidental but valuable result of my invention is the elimination of the so-called "Edison effect," which renders the lamps of my invention peculiarly suited for high-voltage work, though the large filaments which I find give the best results also render the lamps suitable for series circuits carrying currents of considerable magnitude, on which the voltage consumed in each lamp is usually relatively low.

The advantages of a large filament may to a considerable extent be realized by the use of a small filament in concentrated form as a coil or spiral form, as shown in Fig. 2. Moreover, as already indicated, the winding of a large diameter filament in concentrated form, as by coiling, still further increases the efficiency attainable.

Fig. 3 shows a lamp in which the spiral filament 12 is located practically at the center of the bulb 13 and is supported by heavy bare tungsten leads 14. The lamp of Fig. 3 differs from the lamp of Fig. 2 in that the bulb is spherical instead of elongated. In this case the bulb must be of considerable size, and in fact in all cases it is better that the bulb should be of relatively large size with respect to the filament in order to avoid overheating.

The heavy tungsten leads 14 are capable of enduring the intense heat of the gases without giving off water-vapor, and these gases as they rise become cooler so that when they reach the seal 15 and the adjacent glass parts, they are prepared to deposit the tungsten which they carry with them and at the same time do not cause harmful heating. I find however that the use of long tungsten leads, though highly desirable, is not essential. For example, in Fig. 4 and Fig. 5 I have shown an arrangement by which the filament may be so supported that the hot gases which arise from it do not come in contact with the seal or with the supports. This result is secured in Fig. 4 by locating the filament 16 above the seal or glass support 17, in which case the filament may be carried by short leads 18, which may be of tungsten, molybdenum, or other suitable material, which may extend up from the seal 17. Similarly in Fig. 5, the seal 19 extends in from the side of the bulb horizontally.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. In an incandescent lamp, the combination of the closed lamp bulb, a gaseous filling therein of substantial pressure at the operating temperature of the lamp and of substantially poorer heat conductivity than hydrogen, and a filament of such high melting point and low vapor pressure that it may be operated during a long useful life at a temperature higher than that of a tungsten filament operating in a vacuum at an efficiency of one watt per candle.

2. In an incandescent lamp, the combination of the lamp bulb, a gaseous filling therein of considerable pressure at the operating temperature of the lamp and of poor heat conductivity, and a filament of metal having such high melting point and low vapor pressure that the filament may be operated during a commercially useful life at a temperature higher than the temperature of the filament of a vacuum tungsten lamp operating at an efficiency of one watt per candle.

3. In an incandescent lamp, the combination of the lamp bulb, a gaseous filling therein of substantial pressure at the operating temperature of the lamp and having a heat conductivity poorer than that of hydrogen, and a filament of large effective diameter and of metal having high melting point and low vapor pressure so that the filament may be operated during a long useful life at a temperature and at an efficiency higher than would be permissible to give the same useful life if the filament were operated in a vacuum.

4. The combination of a lamp bulb, a filling therein of dry nitrogen at a pressure materially in excess of that corresponding to 50 millimeters of mercury and a filament of tungsten of large effective diameter, the filament being thereby adapted for operation at a temperature higher than that which it would have if operated in a vacuum at an efficiency of one watt per candle.

5. An incandescent electric lamp having a filament of tungsten of large effective diameter and a bulb or globe therefor filled with dry nitrogen at a pressure as high or higher than that corresponding to 300 millimeters of mercury, the filament being thereby adapted for operation at a temperature higher than that which it would have if operated in a vacuum at an efficiency of one watt per candle.

6. An incandescent electric lamp having a filament of large effective diameter formed of refractory metal having very low vapor pressure, and a bulb therefor filled with a gas of poorer heat conductivity than hydrogen and at a pressure exceeding that corresponding to 50 millimeters of mercury, the filament being thereby adapted for operation at a temperature higher than that which it would have if operated in a vacuum at an efficiency of one watt per candle.

7. An incandescent lamp consisting of a lamp bulb, a filament of a material having a high melting point and low vapor pressure located therein, the upper portion of the lamp bulb serving as a condensing chamber or deposit chamber for material vaporized from the filament, a gas or vapor of poorer heat conductivity than hydrogen and of a pressure materially in excess of that corresponding to 50 millimeters of mercury, and a filament so proportioned in size that the lamp will emit light at an efficiency higher than the efficiency the filament would have in a vacuum if operated so as to have approximately the same useful life.

8. An incandescent lamp having a lamp bulb provided with a space serving as a deposit chamber, a filament of a material having a high melting point and low vapor pressure located below the deposit chamber, and an atmosphere in the bulb consisting of a pressure of gas or vapor materially in excess of 50 millimeters of mercury and having poorer heat conductivity than hydrogen.

9. An incandescent lamp having a lamp bulb provided with a space serving as a deposit chamber, a filament located below the deposit chamber, and an atmosphere in the bulb consisting of a pressure of a poor heat conducting gas materially in excess of 50 millimeters of mercury, the said filament being of such diameter and of such material that it may be operated at a temperature in excess of that of a tungsten filament operating in a vacuum at an efficiency of one watt per candle for a long time before wasting away to such a point as to break or become of unduly high resistance.

10. The combination in an incandescent lamp having during operation an atmosphere in the bulb of relatively high pressure and of poorer heat conductivity than hydrogen, of a filament of a material having a high melting point and low vapor pressure and capable of operation without undue blackening of the bulb for a reasonable commercial life at an efficiency higher than could be obtained with the same length of life with such a filament in a vacuum.

11. The combination of a closed bulb or container, a gaseous filling therein of a pressure when the device is in operation materially in excess of that corresponding to 50 millimeters of mercury and of substantially poorer heat conductivity than hydrogen, and a filament of large effective diameter, and of material of such high melting point and low vapor pressure that it may be operated during a long useful life at an efficiency better than one watt per candle.

12. In an incandescent lamp, the combination of the lamp bulb, a tungsten filament therein, and a gaseous filling, the effective diameter of the filament being sufficiently large and the heat conductivity of the filling being sufficiently poor to permit the lamp to be operated with a filament temperature in excess of that of a vacuum tungsten lamp operating at an efficiency of one watt per candle and with a length of life not less than that of such a lamp.

13. An incandescent electric lamp having a closely coiled tungsten filament, the coil

giving the effect of a filament of large diameter, an inclosing bulb and a filling of gas having a materially poorer heat conductivity than hydrogen and at a pressure as high or higher than 300 millimeters of mercury, the filament being adapted for operation in said gaseous filling at a temperature higher than that which it would have if operated in a vacuum at an efficiency of one watt per candle.

In witness whereof, I have hereunto set my hand this eighteenth day of April, 1913.

IRVING LANGMUIR.

Witnesses:

W. J. GREGAN,
LEO C. FOSS.