Sept. 29, 1953 G. A. FREEMAN ET AL 2,654,043

DISCHARGE LAMP, METHOD OF OPERATING, AND METHOD OF MAKING

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Fig. 1.

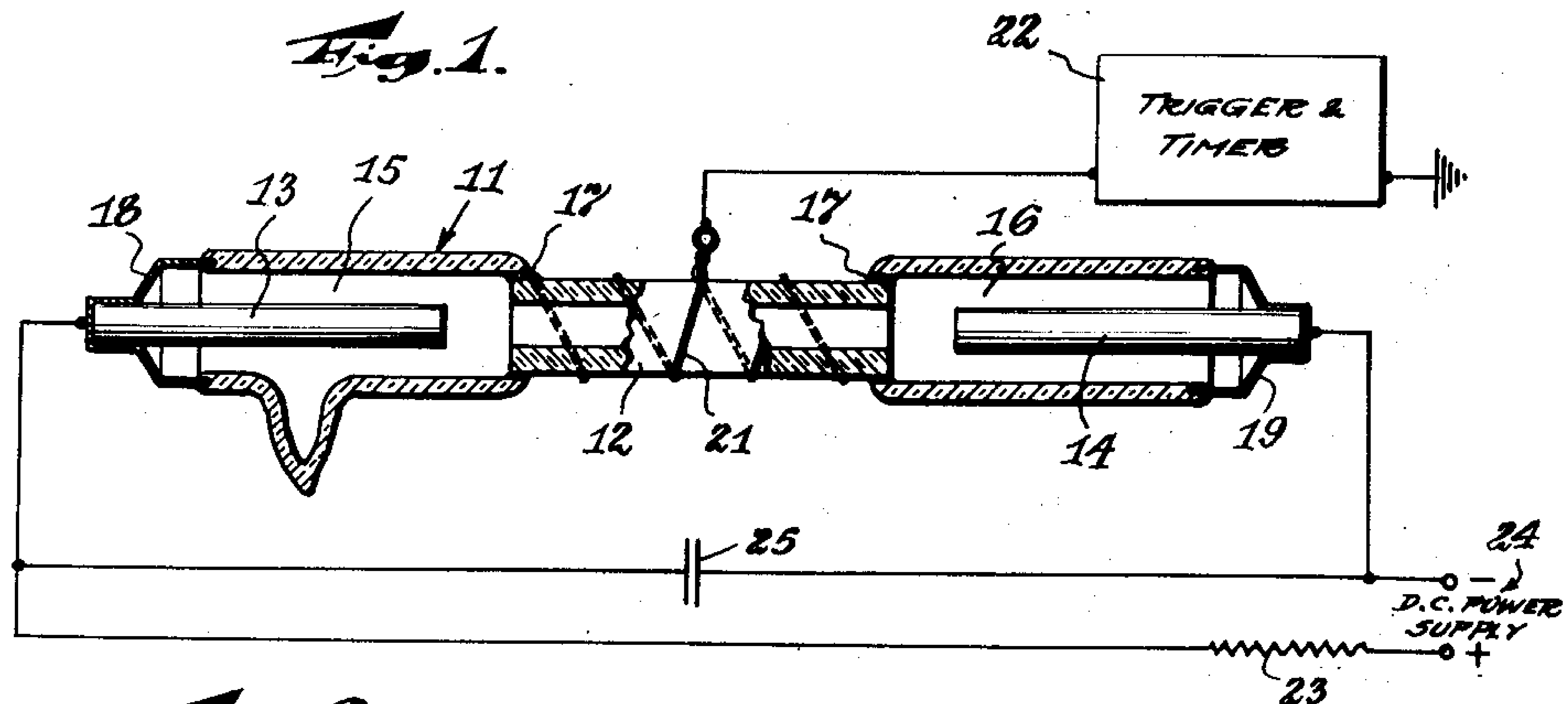


Fig. 2.

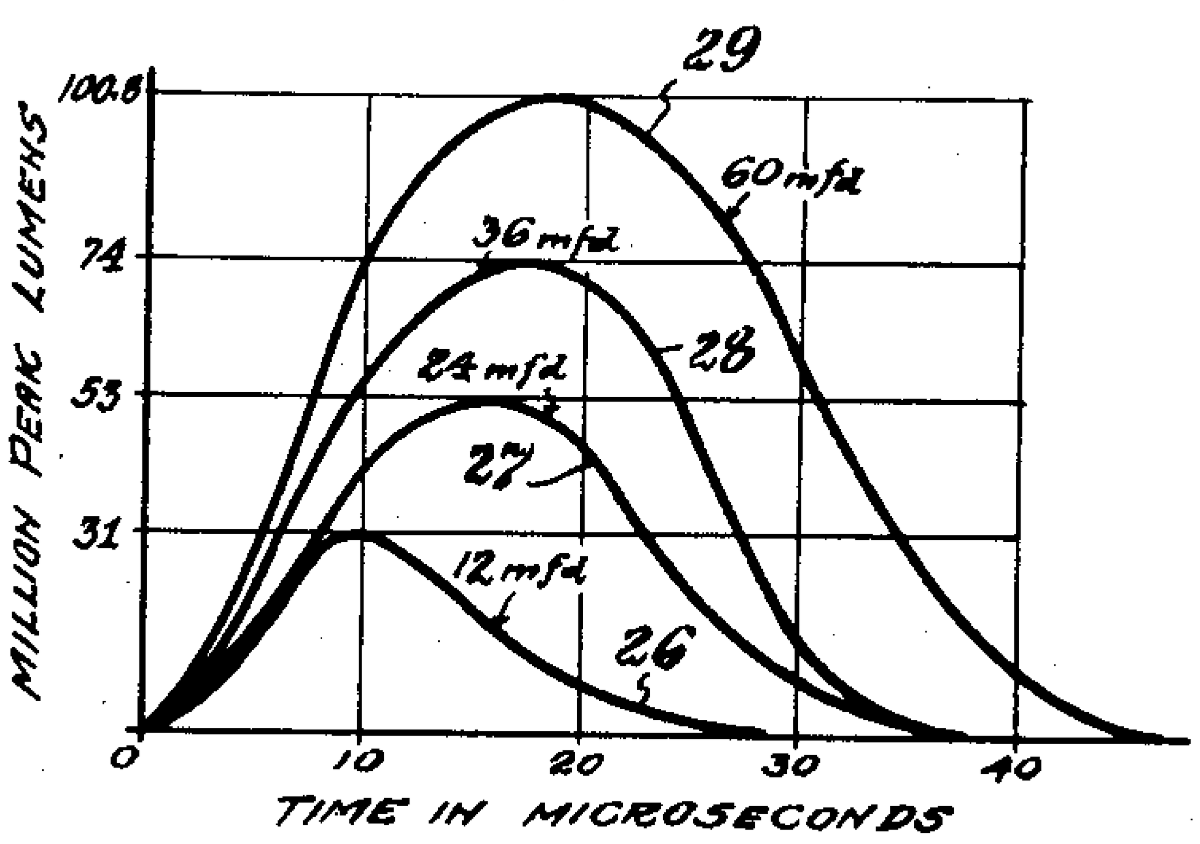


Fig. 4.

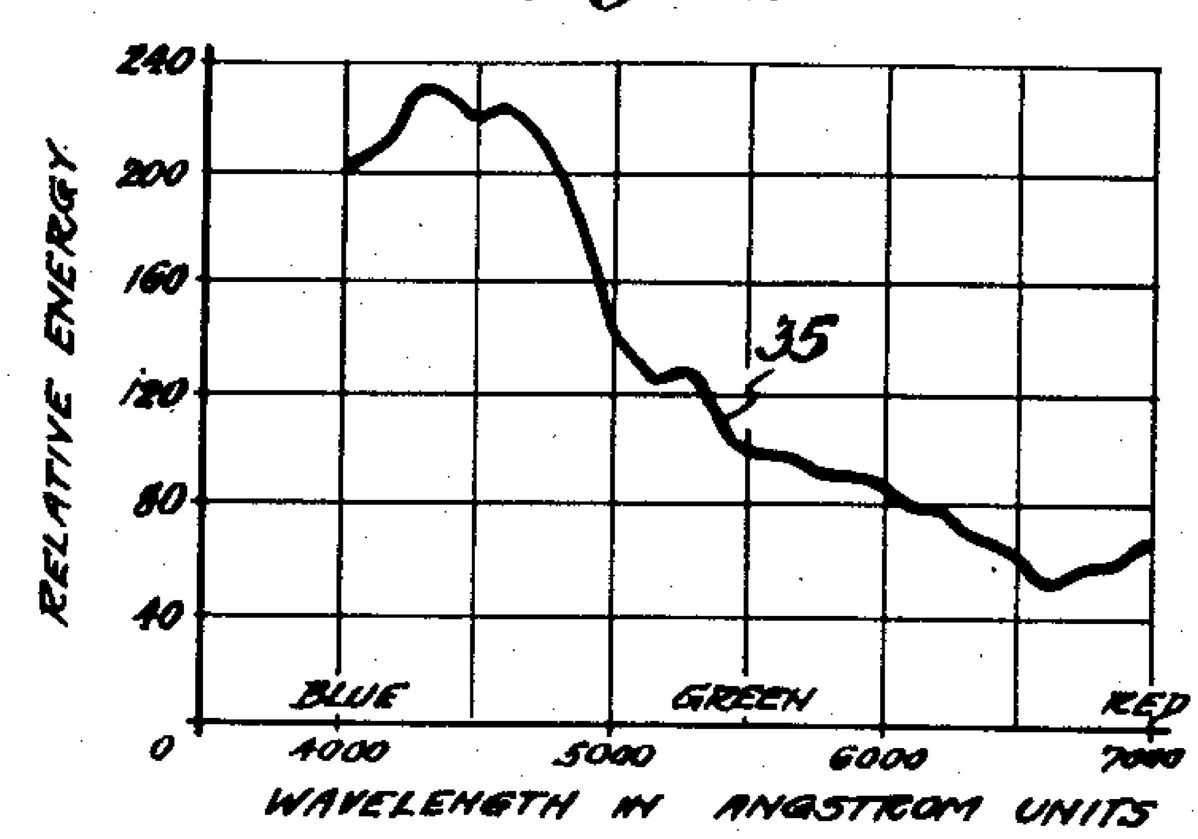


Fig. 3.

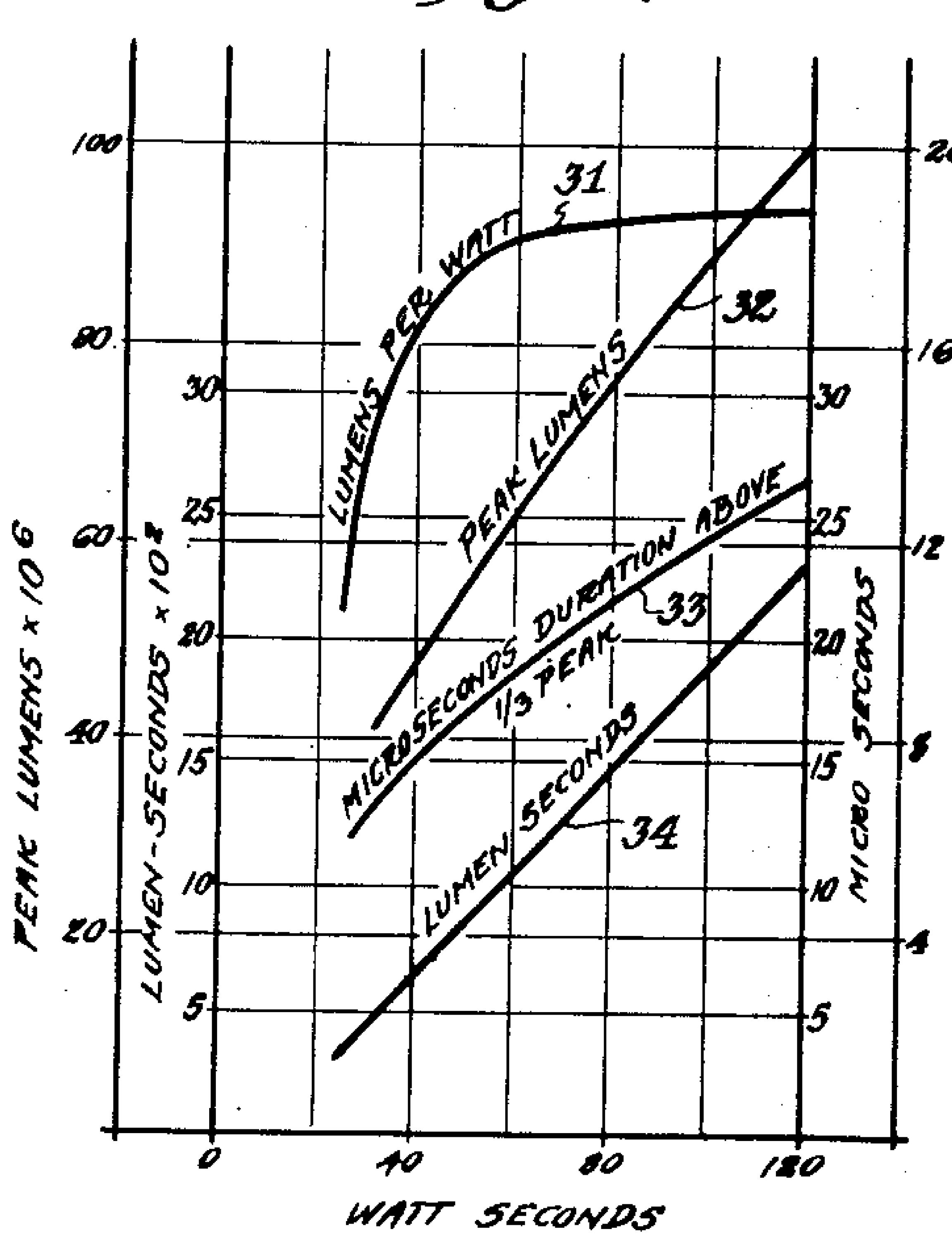
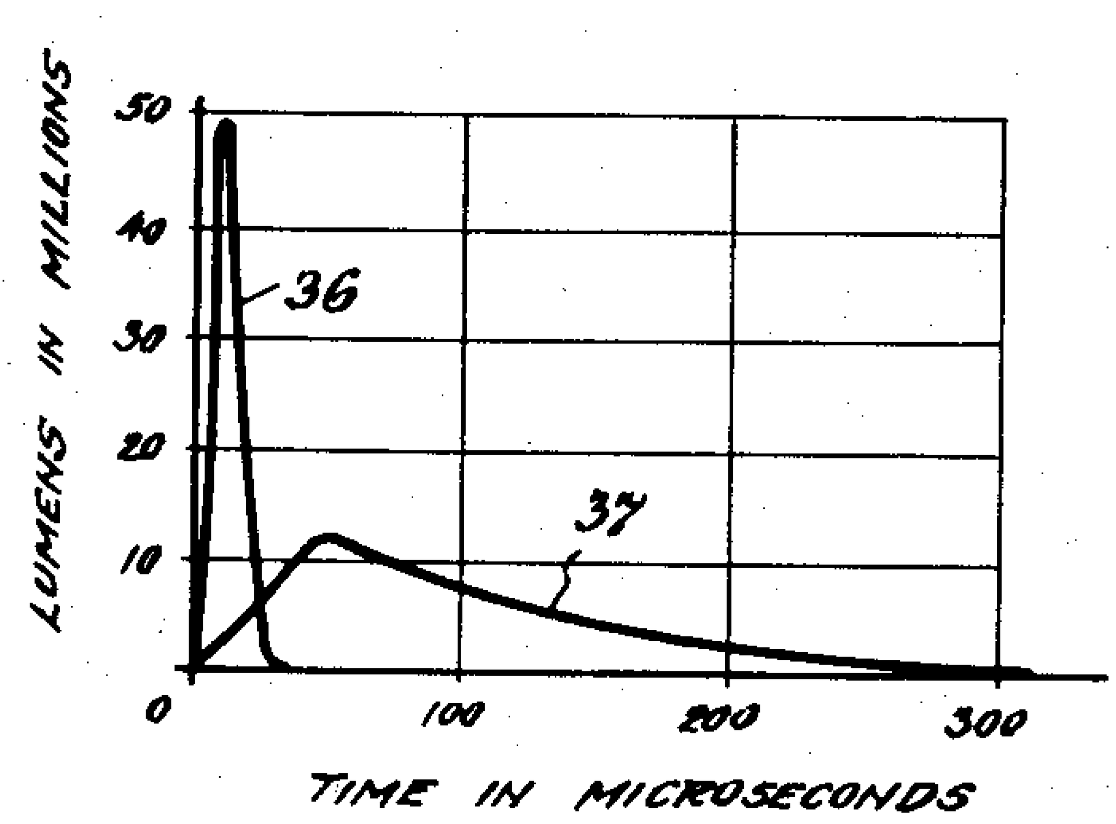


Fig. 5.



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DISCHARGE LAMP, METHOD OF OPERATING, AND METHOD OF MAKING

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7 Claims. (Cl. 313—185)

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This invention relates to discharge lamps and more particularly to such which may furnish instantaneous flashes of light of high intensity.

The principal object of our invention, generally considered, is to provide a durable lamp which efficiently emits intense flashes of light at desired time intervals.

Another object of our invention is to provide a discharge lamp, the envelope of which has a fused quartz tubular portion united at its ends to electrode-containing glass chambers which serve to collect quartz powder vaporized during operation.

A further object of our invention is to provide a discharge lamp adapted to emit intense flashes of light and which comprises an intermediate fused quartz tubular envelope portion and metal terminals holding inwardly-extending tungsten electrodes at each end thereof, said metal terminals being connected to the respective ends of said tube by graded seal portions forming end chambers large enough to cushion the sudden expansion of gas in the tube during a flash.

A still further object of our invention is to operate a lamp such as above described at higher than usual power to thereby avoid blackening and improve the operation in general.

An additional object of our invention is to initiate the operation of a discharge lamp, such as above described, by the employment of a trigger having a plurality of loops disposed around the quartz tubular portion to thereby avoid inconsistent firing.

Other objects and advantages of the invention will become apparent as the description proceeds.

Referring to the drawing:

Figure 1 is an axial sectional view to scale of a lamp embodying our invention with parts shown in elevation, and an operating circuit indicated diagrammatically.

Figure 2 is a graph illustrating typical relations between light intensity and duration of flash from a lamp embodying our invention.

Figure 3 is a graph illustrating how certain of the characteristics, such as the output in lumens per watt, the peak lumens, the duration of the flash above one third of the peak, and the lumen seconds output, vary with the energy in each flash in terms of watt seconds, for a lamp embodying our invention.

Figure 4 is a graph showing the spectrum distribution of the light from a lamp embodying our invention.

Figure 5 is a graph comparing the light output

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and the duration of the flash for a lamp embodying our invention with those of a standard photographic flash tube, when the input of each is 48 watt seconds per flash.

A new flashing lamp has been developed especially for safe landing of aircraft under all weather conditions. Instrument flying brings a plane close to the airport where a new lighting system using lamps according to our invention provides the pilot the assurance that only direct vision can give as to the runway location.

Tests conducted during the war have shown that a light can penetrate useful distances in dense fog, providing extremely high candlepower is used. The new light source, ten times the sun's brightness, has been combined with a large parabolic reflector to concentrate more than three billion candlepower in a narrow beam to obtain the required fog penetration. Thirty-six such units are installed at ground level, spaced in a line 3200 feet long, to guide a pilot down to the airport runway.

Flashing light was selected as the only means of obtaining the required intensity and still not blind the pilot as he approached more closely. Only a few watts average power is used by a flashing lamp but the peak power in the flash is millions of watts. Extreme light intensity is produced, lasting a few millionths of a second. Such a lamp is operated from energy accumulated in a condenser which is released at the desired instant by means of an ignition spark applied to the lamp. Before ignition, the lamp is non-conducting. A high voltage spark, similar to automobile ignition, ionizes the gas in the lamp causing its resistance to suddenly drop from near infinity to less than one ohm, discharging the condenser almost instantly. The intensity of light, even though of very short duration, is many times greater than is obtainable from a continuously burning lamp. The series of flashes is repeated 40 times per minute to keep the pilot informed of the location of the runway until the landing is made.

In determining the proper flashing lamp design, commercial photographic flash tubes were considered first. The rapidly repeating flash requirement was found to shorten lamp life excessively unless very low energy per flash was used. Low flash energy was found to result in very low lamp efficiency. A more rugged flashing lamp was required that also had the maximum possible light intensity.

The flashing lamp that was finally developed is shown in Figure 1. Fused quartz is used and special provision made to collect vaporized quartz powder where it will not obstruct the light output. The central portion of the lamp is a tough vitreous tube, thick-walled to insure long life, about two inches long and about one fifth of an inch inside diameter. A graded seal is employed at each end to hermetically seal the low thermal expansion quartz to the higher thermal expansion metal terminals. The graded seals have larger diameter than the quartz tube and form end cavities which act as shock absorbers for the sudden expansion of gas during a flash. The vaporized quartz powder is blown into the end cavities where it is harmless since there it cannot absorb light output. As the lamp is used, the thick quartz wall gradually wears away on the inside until eventual break-through causes the lamp to fail.

The new flashing lamp has been standardized as with a rating of about 50 watt seconds per flash when operated at 40 flashes per minute. The power is supplied from a 2000 volt charge on a 25 microfarad condenser. The rate of energy consumption during the flash is obtained by dividing the energy per flash by the flash duration and is found to be 3,000,000 watts. The brightness is obtained by dividing the output in a direction perpendicular to the lamp axis by the size of the light source viewed from the same direction, and is found to be 10,000,000 candlepower per square inch.

The flash current is calculated using the formula for the discharge of condenser $T=RC$. Since C is made 25 microfarads and T is measured to be 17 microseconds, R is found to be .68 ohm. With 2000 volts applied to .68 ohm, the peak current estimated by Ohm's law is 2940 amperes. The average power used in the lamp is obtained by dividing the energy per flash by the interval between flashes and is found to be only 33 watts.

Krypton gas is used in the lamp to obtain the maximum light efficiency. Argon gas will give about 80% as much light and nitrogen still less.

Referring to the drawing in detail, like parts being designated by like reference characters, there is shown in Figure 1 a lamp embodying our invention and comprising an envelope **11** with an intermediate tubular portion **12**, preferably formed of tough transparent vitreous material such as fused quartz, fused magnesia, fused alumina, or similar refractory material. In a preferred embodiment, the intermediate portion **12** is about 2'' long, has an inside diameter of about 4 millimeters or ⅕'', and a wall thickness of about 3 millimeters. The envelope **11** holds a pair of electrodes **13** and **14** desirably formed of tungsten, molybdenum or similar refractory or high melting point metal. In a preferred form, they consist of relatively heavy solid or non-tubular, as distinguished from hollow, tungsten cylinders, that is such about ⅛'' in diameter that is, nearly as large as the bore of the portion **12**, and about 1⅝'' long, presenting to one another flat faces relatively large in area. These electrodes are disposed in end chambers **15** and **16**, respectively extending from opposite ends of the quartz tubular portion **12**. The end chambers are formed as graded seals, desirably hermetically sealed to the quartz tube after first beading the ends of the latter with rings of special flux glass **17**, using a glass lathe.

The graded seal portions forming the end chambers **15** and **16** may be sealed directly to the electrodes **13** and **14**, respectively. Preferably, each electrode has its outer end portion fitting in an end cup or cap **18** or **19**, and the caps are in

turn sealed to the respective ends of the graded seal portions **15** and **16**. The cups **18** and **19** are desirably formed of material which seals well to the glass of the end chamber members **15** and **16**. For that purpose, they may be formed of "Kovar" as defined in the Lempert et al. Patent No. 2,279,831, dated April 14, 1942, or other suitable metal. Such cups are desirably degreased, baked in humid hydrogen, the tungsten electrodes chamfered at their outer ends, then degreased and spot welded to the "Kovar" cups. Rings of brazing wire are then formed, degreased, and two rings applied over each electrode. A boat is used to hold each electrode assembly in a vertical position with the "Kovar" cup down. Heating in a humid hydrogen atmosphere at about 1010° C. for about 20 minutes serves to braze each electrode to its cup, thereby making a good electrical connection therebetween.

Before securing the cup to the corresponding end chamber member, its edge is desirably first glassed, as on a lathe, oxidation removed as in a hot anodic alkaline electrocleaner, the parts rinsed in clean water, neutralized, again rinsed, and then dried.

An assembled electrode and cup is secured to its graded seal and the latter to the quartz tube, preferably in the following manner. A graded seal with a protective ring of asbestos ribbon around its end is held in a lathe head chuck and a quartz tube with one end plugged with asbestos is held in the tail chuck. The adjacent ends of the parts are sealed, care being taken to avoid sealing to an unfluxed part of the quartz tube.

The tail chuck is disengaged and the asbestos plug removed from the quartz tube. The second graded seal, with one end corked and with a protective ring of asbestos ribbon around the end, is placed in the tail chuck and a second seal made as before.

The tail chuck is disengaged and the cork removed from the graded seal. An electrode assembly is placed in the tail chuck and sealed to a graded seal, care being taken that the electrode is not oxidized. A hole may be blown for the exhaust tubulation and an exhaust tube sealed thereabout. The tail chuck is disengaged and the exhaust tube may be bent around so it can be engaged in the tail chuck, care being taken that the exhaust tubulation is disposed axially of the assembled lamp part. The graded seal is desirably annealed while the exhaust tube is being held by the tail chuck.

The assembly is removed, turned around and put into the head chuck, where it is held by the exhaust tubulation, and an electrode assembly is placed in the tail chuck, sealed to the graded seal and annealed, completing the assembly.

The complete assembly is then desirably connected to a vacuum pump and tested for leaks with a spark coil. The lamp is then exhausted, baked, and then filled with an inert gas such as argon or nitrogen at a pressure of about 150 millimeters and tested by flashing two minutes at three flashes per second, using a 24 microfarad condenser charged to about 2000 volts. The polarity is reversed and this is repeated. Triggering is accomplished with the spark coil applied to the center of the quartz tubing. The lamp is then reevacuated and filled with krypton gas to a pressure of about 325 millimeters. The lamp is then preferably flashed for about two minutes at about 40 flashes per minutes on 24 microfarad condenser with a potential of 2000 volts. The lamp is then tipped off, care being taken to avoid strain in the graded seals.

In order to avoid inconsistent firing during use, by getting more complete gas ionization, we desirably employ a trigger 21, desirably formed of suitable wire such as 15 mil spring steel or nickel and wound several times around the quartz tube 12, as illustrated, an intermediate portion thereof, between end portions which encircle the tube, being connected to the timing mechanism indicated at 22. For flashing, the lamp is connected through a resistance 23 to a source of direct current 24, in parallel with a condenser 25.

The new lamp above described avoids the use of an outer bulb and vaporized quartz collected in a way to obscure the light output. Natural cooling of the lamp is thus not impeded. Enlarged or relatively large end chambers 15 and 16 serve to collect the vaporized quartz, since the rapid expansion of gas during a flash blows whatever is vaporized into them. This has been found to work out quite well in practice, even with loadings higher than 20 watts average. No starting electrode seal is needed, since it has been found that a wire, such as indicated at 21, wrapped around the quartz tube portion 12 at the center of the lamp serves as well. The new lamp lends itself to forced cooling for higher loadings better than any previously employed. The employment of "Kovar" cups, such as indicated at 18 and 19, rather than glass flares connected directly to the tungsten electrodes, has avoided considerable shrinkage due to cracking of the glass flares.

The lamp of our invention was first tested at 20 to 30 watt seconds per flash from 40 to 60 per minute. After 10 to 20 hours the various lamps tested all developed some blackening obscuring the light output and voltage breakdown became high so that triggering was inconsistent. We therefore stepped up the power per flash to 38 watt seconds and later to 50 and even as high as 325. Contrary to expectations, the operation at higher loading gave excellent results. Blackening was not only avoided, but blackened lamps would become clean by raising the power per flash. The voltage break-down became more consistent and lamps which had become hard to start were made to start well again by operating for a while at higher power per flash.

Examination of dissected lamps showed that silica powder collected in a hard thick layer on the electrodes. When run at low power per flash the electrodes coated over completely and the starting voltage became high. When run at high power per flash, the tip of the electrode would be cleaned off or kept clean, while powder still remained on the electrode back of the tip where it did no harm. Examination of the quartz intermediate tube showed that the inside diameter was increasing with lamp operation due to the evaporation of the quartz at the high loadings. It is obvious that any incipient black deposit is removed by the evaporation of the quartz which is blown into the ends of a lamp around the electrodes.

Figure 2 shows the characteristics of the lamp of our invention with changes in the capacity of the condenser 25. With a condenser of 12 microfarad capacity, it will be seen that peak intensity of the flash is only about 31 million lumens as indicated by the graph 26. When the condenser capacity is doubled, the peak lumens increased to 53 million, as indicated by the graph 27. When tripled, it increases to 74 million, as indicated by the graph 28. When the condenser is increased to 60 microfarads, the peak intensity is 100.8 million lumens, as indicated by the graph 29.

Figure 3 shows other characteristics of the lamp of our invention. In terms of watt seconds per flash, the lumens per watt increase along the curve 31, the peak lumens increase along the curve 32, the duration of the flash above $\frac{1}{3}$ peak increases along the curve 33, while the lumen seconds output varies in accordance with the curve 34.

A consideration of the graph 35 in Figure 4 will show the spectral distribution of the light output from the lamp when flashed at 2000 volts, 48 watt seconds per flash. It will be seen that the light emitted is richer in radiation near the blue end of the spectrum, so that the light appears bluish white and is particularly suitable for photographic work because of its content of actinic rays.

Figure 5 is a graph comparing the output of a lamp in accordance with our invention having a 48 watt seconds input per flash, as indicated by the curve 36, with the output as indicated by the curve 37 of a standard photographic flash lamp, having an input of 48 watt seconds. By "standard" photographic flash lamp, we mean one of the type designated FT-14 by Harold E. Edgerton in his article entitled "Photographic use of Electrical Discharge Flashtubes," beginning on page 390 of volume 36, No. 7, Journal of the Optical Society of America, July, 1946; and described by F. E. Carlson and D. A. Pritchard in their article entitled "The Characteristics and Application of Flashtubes," presented at the Annual Convention of the Illuminating Engineering Society, Quebec, Canada, September 18 to 20, 1946.

The flash tube of this invention has a shorter duration and higher peak output than other known photographic flash lamps, as graphically disclosed in Figure 5, because a short arc gap with a relatively high gas pressure is provided that will have lower resistance to the flash current than a long straight or coiled discharge tube in which the gas pressure is quite low. The same quantity of energy is used up faster in the lamp of this invention. As a result, the flash does not last as long and the intensity of the light, being proportional to the rate of energy consumption, is much higher.

Although preferred embodiments of our invention have been disclosed, it will be understood that modifications may be made within the spirit and scope of the appended claims. For example, although krypton gas is specified as preferred, yet gas containing a major proportion of krypton, say 90%, and a minor proportion of xenon, say 10%, gives an output approximating that when pure krypton is used. Other rare or noble gases, such as argon, xenon, neon, helium, or mixtures, may be employed if the corresponding variations in output are permissible. The effect of pressure, of krypton, for example, on light efficiency was found to be relatively unimportant, so that the most advantageous pressure for the desired breakdown characteristics may be used.

Although we do not wish to limit ourselves to the size of the bore of the intermediate tubular portion 12, yet we may desire to decrease it or make it so small that the discharge therethrough is saturated, that is, fills the entire cross-section of the bore and cannot be further increased at the pressure used by increasing the size of the condenser. Use at saturation currents not only means that the spectral characteristics of the flashes are uniform, but that blackening is avoided.

We claim:

1. The method of making a discharge device comprising forming end chamber portions as graded seals, forming a pair of solid cylindrical metal electrodes, chamfering an end of each electrode for fitting in an end cup, fitting the chamfered end of each electrode into a cup of "Kovar" and spot welding it thereto, placing rings of brazing wire over each electrode, heating each electrode and associated cup in humid hydrogen at a temperature of about 1010° C. for about 20 minutes to braze each electrode to its cup, glassing the free edge of the cup of each electrode assembly, holding one of said graded seals with a protective ring of asbestos ribbon around its end in a lathe head chuck and a quartz intermediate portion tube with one end plugged with asbestos in the tail chuck of said lathe, sealing the adjacent ends of the parts, using a special flux glass on the quartz tube, disengaging the tail chuck and removing the asbestos plug from the quartz tube, plugging a second graded seal and holding it with a protective ring of asbestos ribbon in the tail chuck, making a second seal between it and the other end of said quartz tube, placing an electrode assembly in the tail chuck and sealing it to a graded seal, care being taken to avoid oxidation of the electrode, removing the assembly, turning it around and holding it in the head chuck, placing the other electrode assembly in the tail chuck, and sealing it to the other graded seal.

2. A discharge lamp comprising an intermediate fused quartz tubular portion, thick-walled to insure long life metal cup terminals one at each end thereof, graded seal glass portions forming end chambers with said metal cup terminals and hermetically sealing the respective ends of said low thermal expansion quartz portion to the higher thermal expansion metal terminals to complete the envelope of said lamp, a solid or non-tubular cylindrical refractory metal electrode, nearly as large in diameter as the bore of the tubular portion, extending inwardly from each metal terminal, disposed in the adjacent chamber, presenting to one another flat faces relatively large in area, and aligned axially with said envelope, each metal terminal having an inwardly opening socket, in which the outer end portion of its electrode is received and brazed, and a flange portion surrounding and spaced from its electrode, the free edge portion of said flange being hermetically sealed to the adjacent edge portion of said graded seal portion, and a filling of rare gas in said envelope.

3. A gas-filled discharge lamp comprising a thick-walled quartz tube about 2″ long and ⅕″ inside diameter, a graded seal glass chamber of larger diameter hermetically sealed to each end of and communicating with said tube, and solid refractory metal electrodes, nearly as large in diameter as the bore of said tube, presenting to one another flat faces relatively large in area, disposed axially of said tube, one in each chamber.

4. A discharge lamp comprising an envelope, said envelope having an intermediate fused quartz tubular portion, thick-walled to insure long life, and metal cup terminals at each end thereof, said metal cup terminals closing the envelope and being hermetically sealed to the respective ends of said tube by graded seal portions forming end chambers and completing the envelope, a solid or non-tubular cylindrical refractory metal electrode, nearly as large in diameter as the bore of said tubular portion, extending inwardly from each metal terminal, disposed in the adjacent chamber, and aligned axially with said envelope, and a rare gas filling in said envelope.

5. A gas-filled discharge lamp comprising an outer tube of translucent refractory material selected from the group consisting of fused quartz, fused magnesia, and fused alumina, a glass chamber hermetically sealed to each end thereof, metal cup terminals at the outer ends of said glass chambers, and a solid or non-tubular metal electrode, nearly as large in diameter as the bore of said tube, in each chamber, presenting a flat surface to the other electrode with its outer end secured to the inner surface of the corresponding terminal, and disposed axially of said tube.

6. A discharge lamp comprising an intermediate tube of translucent refractory material selected from the group consisting of fused quartz, fused magnesia and fused alumina, about 2″ long, ⅕″ inside diameter and 3 mm. wall thickness, metal cup terminals one at each end of said lamp, graded seal glass portions, of a diameter larger than said refractory portions, forming end chambers with said metal cup terminals and hermetically sealing the respective ends of said refractory portions thereto to complete the envelope of said lamp, a solid or non-tubular cylindrical tungsten electrode about ⅛″ in diameter and 1⅝″ long extending inwardly from each metal terminal, disposed in the adjacent chamber, presenting a flat surface to the other electrode and aligned axially with said envelope, each metal terminal having an inwardly opening socket in which the outer end portion of its electrode is received and connected, and a flange portion surrounding and spaced from its electrode, the free edge portion of said flange being embedded in, and hermetically sealed to, the outer edge portion of the adjacent glass end chamber, and a filling of noble gas comprising a major proportion of krypton at a pressure of about 325 millimeters in said envelope.

7. The method of making a discharge device comprising forming end chamber portions as graded seals, forming a pair of solid cylindrical refractory metal electrodes, fitting an end of each electrode into a metal cup and electrically connecting it thereto to make the electrode assemblies, glassing the free edge of the cup of each electrode assembly, holding one of said graded seals with a protective ring around its end in a lathe head chuck and a quartz intermediate portion tube with one end plugged in the tail chuck of said lathe, sealing the adjacent ends of the parts, disengaging the tail chuck and unplugging the quartz tube, plugging a second end chamber portion and holding it with a protective ring in the tail chuck, making a second seal between it and the other end of said quartz tube, placing an electrode assembly in the tail chuck and sealing it to a graded seal, removing the assembly, turning it around and holding it in the head chuck, placing the other electrode assembly in the tail chuck, and sealing it to the other graded seal.

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