

- [54] **SELECTIVE SPECTRAL OUTPUT METAL HALIDE LAMP**
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- [22] Filed: **Jan. 17, 1972**
- [21] Appl. No.: **218,491**

Related U.S. Application Data

- [63] Continuation-in-part of Ser. No. 863,732, July 7, 1969, abandoned.
- [52] U.S. Cl. **313/184; 313/225; 313/229**
- [51] Int. Cl. **H01j 61/18**
- [58] Field of Search 313/229, 227, 225, 184

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[57]**ABSTRACT**

A high pressure metal halide vapor arc lamp providing radiation concentrated in selected spectral bands. The filling comprises metal halide buffer species in addition to metal halide emitter species. The buffer species increase the energy input to the arc, thereby augmenting the radiation from the emitter species. The radiation from the buffer species may be negligible or is largely suppressed. A lamp emitting in the blue, green and red bands comprises a limited quantity of ZnI_2 as buffer species which serve to augment the radiation from LiI and TlI present as emitter species, optionally with a limited quantity of Hg as a secondary buffer.

5 Claims, 2 Drawing Figures

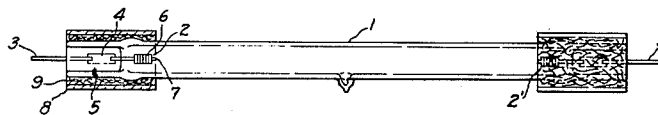


FIG. 1.

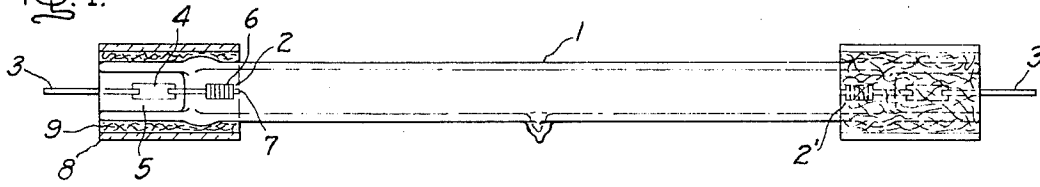
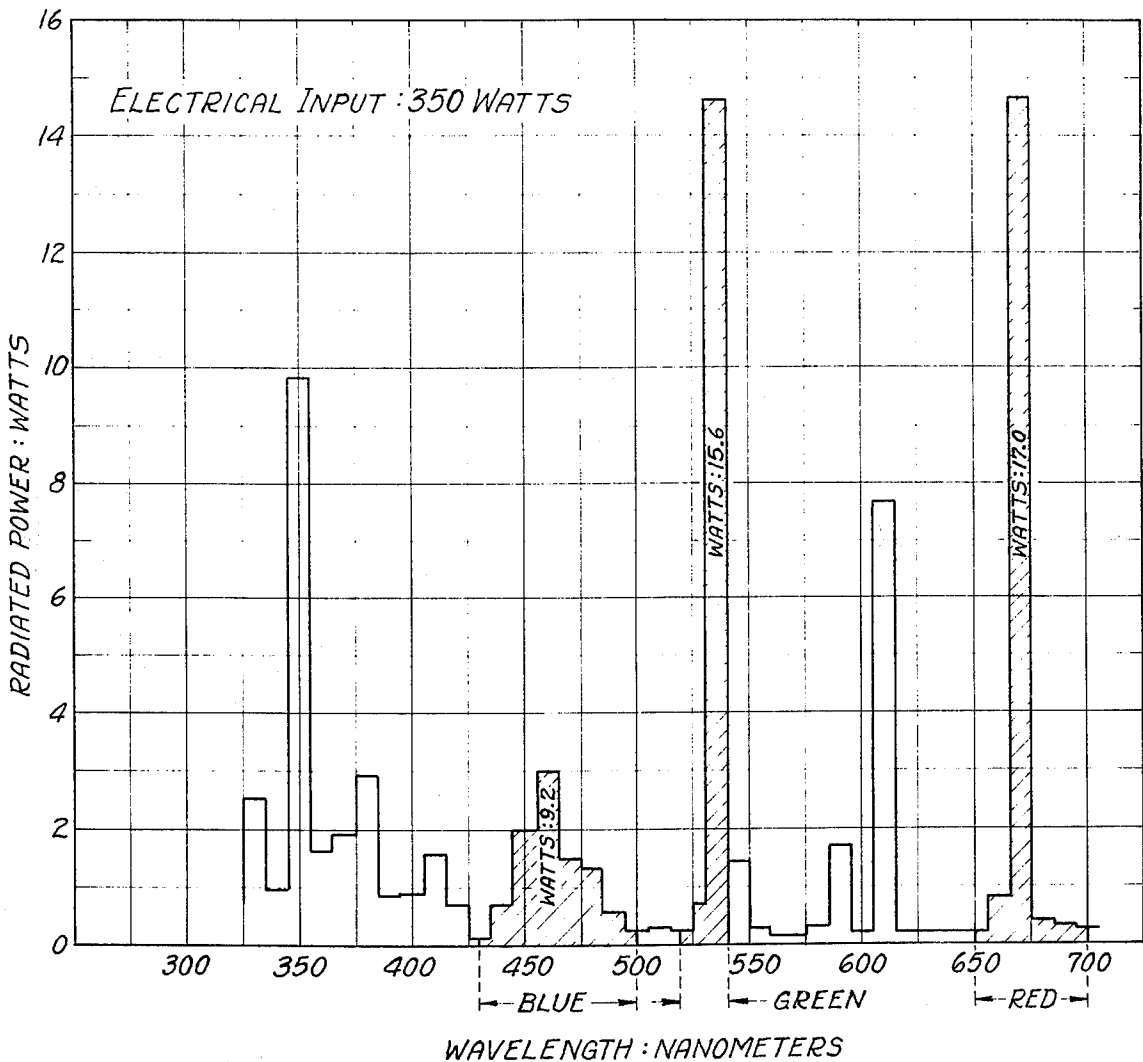


FIG. 2.



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SELECTIVE SPECTRAL OUTPUT METAL HALIDE LAMP

This application is a continuation-in-part of our co-pending application Ser. No. 863,732, filed July 7, 1969, similarly entitled and assigned and now abandoned.

BACKGROUND OF THE INVENTION

The invention relates to high pressure metal vapor lamps using an arc discharge in metal halide vapors to produce light or radiation.

Until quite recently, the mercury arc lamp, notwithstanding its yellowish-green light and poor color rendition, has been pre-eminent among high pressure arc lamps. More recently, it was discovered that a great improvement in color rendition and efficiency could be achieved by using vaporizable metal halides in the fill. A preferred filling taught by U.S. Pat. No. 3,234,421 — Reiling, comprises mercury, sodium iodide, thallium iodide, and indium iodide. This lamp has emission widely scattered throughout the visible light spectrum resulting in good color rendition, and is an excellent light source for general use.

The principal interest in connection with metallic halide additives to mercury vapor lamps has been to improve efficiency and achieve balanced white light output. A particular problem has been to provide sufficient red radiation to achieve good color rendition. In such lamps, the electrical characteristics are essentially those of a mercury discharge.

In some applications involving color synthesis, emission scattered throughout the visible spectrum is undesirable. For instance in reprographic applications for making colored copies, radiation concentrated in the three primary colors, blue, green and red is desired. The three primary colors can be derived from light sources emitting continuously throughout the visible spectrum by means of filters. Three light beams are provided, either from three separate light sources or by splitting the beam from a single source by optical means. Filters are used in each light path to eliminate everything except the desired primary color, and the three primary colors may then be recombined into a single beam. Such systems are prohibitively expensive and inefficient.

In some photochemical application, high energy emission in specific regions or bands is required in order to promote a chemical process, and emission in other bands must be suppressed because it may inhibit the processor produce undesirable reactions.

The object of the invention is to provide efficient high intensity radiation sources having spectral energy output concentrated in specific regions or balanced relative to an overall color requirement.

SUMMARY OF THE INVENTION

In accordance with our invention, a high intensity arc lamp radiating in selected spectral bands or regions has a filling comprising metal halides of which at least one is a buffer species and another is an emitter species. Both buffer and emitter species participate in the discharge but the buffer is the primary determinant of the electrical characteristics of the discharge while the emitter is the primary determinant of the spectral characteristics of the discharge. The buffer controls the electrical characteristics of the discharge primarily by

its effect on the thermal characteristics. The buffer augments the radiation from the emitter species and may also reduce electrophoretic or chemical processes tending to deplete the emitter species or attack the envelope wall. The buffer species is selected for its specific ability in respect of these functions and not primarily for its radiative contribution to the desired spectral output. The emitter species is selected for its specific spectral characteristics.

In a preferred embodiment of the invention wherein the spectral output is concentrated in the blue, green and red bands with energy levels of approximately 1:2:2, the amount of LiI is at least 0.2 mg/cc of envelope volume, the amount of ZnI₂ is from .02 to 1.5 mg/cc, the amount of TlI is from .02 to 3 mg/cc. Optionally there may be provided Hg in an amount less than 1 mg/cc.

DETAILED DESCRIPTION

In general the preferred buffer species are metal halides having the following characteristics:

1. High vapor pressure;
2. High molecular weight;
3. High ratio of halogen to metal in the halide molecule;
4. High ionization potential relative to the emitter species.

In ranking materials, a figure of merit indicative of relative desirability as buffer species is obtained by multiplying the molecular weight of the material, by its vapor pressure at the operating temperature (600° C), by the number of halogen atoms in the metal halide molecule and is given in Table I below.

TABLE I

	Molecular Wgt.	Approx. V.P. at 600° C-torr	Figure of Merit $\times 10^{-4}$	Ionization Potential Electron volts
40	SbI ₃ 503	2×10^4	3000	8.5
	AsI ₃ 456	2×10^4	2700	10.5
	Hg 200	5×10^4	1000	10.4
	BiI ₃ 590	5×10^3	900	8.0
	InI ₃ 496	3×10^3	450	5.8
	InI 242	3×10^3	150	5.8
45	ZnI ₂ 319	10^2	6	9.4
	CdI ₂ 366	50	4	9.0
	Se 79	240	2	9.7
	PbI ₂ 461	20	2	7.4
	TlI 255	35	1	6.1
	SbI ₃ 426	7×10^{-2}	10^{-2}	6.7
	CaI ₂ 294	4×10^{-2}	2×10^{-3}	6.1
50	CsI 250	5×10^{-2}	10^{-3}	3.9
	DyI ₃ 544	2×10^{-3}	3×10^{-4}	6.8
	NaI 150	2×10^{-2}	3×10^{-4}	5.1
	SrI ₃ 531	2×10^{-3}	3×10^{-4}	6.6
	LaI ₃ 520	10^{-3}	2×10^{-4}	5.6
	SrI ₃ 342	10^{-3}	7×10^{-5}	5.7
	LiI 134	5×10^{-3}	7×10^{-5}	5.4
55	BaI ₂ 391	10^{-6}	10^{-7}	5.2

The list is not exhaustive nor does it determine finally the preferability of one buffer over another because other considerations may apply to specific material combinations. Among halides, the iodides are generally preferred because they are less reactive and iodine has the greatest atomic weight among the halogens.

In general, materials suitable as buffer species have a figure of merit greater than 1.0 while materials which may be useful as emitter species have a figure of merit not exceeding 1.0. The materials classified as buffer species in the table have not been used as primary emit-

ters except for InI_3 and InI which have an exceptionally low ionization potential. However in the list of materials where the figure of merit is less than 1.0 are found some of the most desirable emitter species currently used in commercial mercury metal halide lamps, for instance ScI_3 , DyI_3 , NaI and LiI . These are used in lamps where Hg provides the buffer action. The buffer species may have some characteristic radiation which is useful and desired in a particular application. In such case the buffer species determines the desired thermal and electrical characteristics for itself as well as for other emitter species present.

By using two or more buffer materials, the spectral output of the discharge may be greatly increased even though one or more of the buffers contributes little or no direct radiation.

In selecting the buffer species, an important consideration is the ionization potential of the buffers relative to the emitters and to each other. We have found it desirable to have buffer species whose ionization potential is substantially higher than that of any of the emitter species. Also where there is more than one buffer species, the ionization potential of the secondary buffer species should be higher than that of the primary buffer species.

DESCRIPTION OF DRAWING

FIG. 1 illustrates a high pressure tubular lamp embodying the invention.

FIG. 2 shows the spectral output of the lamp of FIG. 1.

PREFERRED EMBODIMENTS

A lamp embodying the invention and illustrating the foregoing principles is designed to radiate predominantly in the blue, green and red bands defined as follows:

Blue	430 - 500 nm.
Green	520 - 540.
Red	650 - 700.

and with energy levels within these bands in the approximate ratio 1:2:2. In this application, radiation in the region between the green and red bands is particularly undesirable and must be kept as low as possible. Mercury in a thermal arc radiates quite strongly at 546 nm which is within the undesirable region and therefore cannot be used as primary buffer species for this lamp.

The foregoing requirements are met by a filling composed essentially of the halides, preferably the iodides, of zinc, lithium and thallium wherein ZnI_2 is the buffer species and LiI and TlI are the emitter species. Preferably there is also included some mercury metal as a secondary buffer and an inert starting gas such as argon at a pressure below 100 torr. The zinc augments the radiation from all three predominant lithium lines but its own radiation is very low, less than 10% of the whole. The mercury radiation in the visible spectrum is almost completely suppressed; however the mercury increases the lamp efficiency and also causes a reduction in the reignition voltage at each cycle.

Referring to FIG. 1, the lamp comprises an arc tube 1 of quartz or fused silica of about 8 millimeters inside diameter and 10 millimeters outside diameter having sealed therein at opposite ends a pair of arcing elec-

trodes 2, 2' defining an arc gap of about 10 centimeters. The volume of the lamp is about 6 cc. The electrode inleads 3 have intermediate thin molybdenum foil sections 4 hermetically sealed through full diameter pinch seals 5 at the ends of the tube. The electrodes each comprise a double layer tungsten wire helix 6 wrapped around a tungsten core wire 7, and may be conventionally activated by thorium oxide applied as a coating on the turns of the helix or filling the space or interstices between turns. In order to heat the end chamber and thus increase the vapor pressure of the metal iodides, a quartz sleeve 8 extending forward up to the electrode tip is fitted over the end of the lamp. The space between the tube wall and the sleeve is filled with a refractory white insulation 9 of quartz fibers.

According to a feature of the invention, we have found that with unactivated tungsten electrodes there is an increase in total light output within the three color bands and less variation in segregation of the various species along the length of the lamp. With activated electrodes, we have measured variations in radiant output of up to 15% within a particular band from end to end of the lamp. This is probably due to the variation in end chamber temperature consequent upon lack of uniformity in activation and resultant work function. By using unactivated electrodes consisting of the previously described tungsten wire helix without activating material of any kind, segregation of species and variation in output along the length of the lamp is reduced to less than 5%. The explanation for the increased total output (about 10%) appears to be that the greater electrode voltage drop in the absence of activation entails additional dissipation of power at the electrodes resulting in increased end chamber temperature and this in turn means more complete vaporization of the various species present. With unactivated electrodes, the arc attachment is diffuse and not concentrated at a hot spot.

PARAMETERS OF THE INVENTION

According to our invention, in order to achieve a high proportion of red it is necessary to have, per cubic centimeter of envelope volume, at least 0.2 milligrams of lithium iodide which is the source of the red radiation. LiI has the lowest vapor pressure of the ingredients of the filling and a saturated vapor is desired. Therefore, LiI is provided in an amount such that if it were the only salt present, an unvaporized excess would remain as a liquid. In fact, the unvaporized excess of LiI forms a liquid phase wherein is dissolved TlI and ZnI_2 . While there is at least in theory no upper limit to the quantity of LiI which may be added, there is no practical benefit in going beyond 2 milligrams per cubic centimeter and the material is wasted.

The amount of zinc iodide required is in the range of .02 to 1.5 milligrams per cubic centimeter of envelope volume. If less than .02 mg/cc of ZnI_2 is provided, the LiI radiation is not appreciably enhanced. Also, the chemical buffering effect of ZnI_2 is insufficient to protect the quartz envelope walls and prevent the depletion of Li from the arc tube. If the quantity of ZnI_2 is greater than 1.5 mg/cc, the voltage gradient becomes excessive when practical levels of Ti are present. For instance the voltage gradient might be 15 volts per centimeter resulting in an arc drop of 525 volts across a 35 centimeter long lamp. A minimum current of 2 to 3 amperes is necessary for reignition and arc stability. The

temperature limitations of quartz require that the dissipation per centimeter of arc length not exceed about 45 watts in the illustrated lamp and thus the resulting limit of about 15 volts per centimeter of gradient imposes the previously mentioned upper limit on zinc iodide.

The quantity of thallium iodide should be between .02 and 3 milligrams per cubic centimeter. The lower limit of .02 mg/cc is imposed by the practical necessity for green in a lamp containing blue and red and which is required to have an overall white appearance. When the upper limit of 3 mg/cc is exceeded, the voltage gradient goes up and the lamp becomes too green. It becomes in fact almost purely a thallium discharge because Tl controls the arc temperature of the discharge; if the pressure of Tl is too high, the arc temperature decreases and the radiation from the other species present, namely red and blue from Li and Zn, decreases and the proportion of green increases yet more.

In lamps according to the invention, ZnI_2 is the primary buffer and mercury is not needed. However a limited quantity of mercury may be provided to achieve certain characteristics. When mercury in an amount not exceeding about 0.25 mg/cc is added, the reignition voltage is reduced by a relatively large factor, as much

ide buffer species, specifically ZnI_2 in accordance with the invention, in a lamp designed to emit in specified spectral bands may be seen from a comparison of the characteristics of the six lamps listed in Table II below. Lamps Nos. 4, 5 and 5X embody the invention, Lamps Nos. 5 and 5X being preferred embodiments. In the column under the heading "Dose mg/cc," the number following the chemical compound is the weight thereof in milligrams per cubic centimeter. Lamps 1 to 5 had a 10 cm arc length and were approximately the same physical dimensions as the lamp previously described and illustrated in FIG. 1 which has a volume of about 6 cc. Lamp 5X had a 35 cm arc length. The output radiation is given in watts in the three bands and has been measured by integrating the intensity over the bandwidths previously specified and comparing it to a standard lamp calibrated in watts output for the same bands. The red efficiency is the ratio of output radiation in the red band measured in watts to the input to the lamp likewise measured in watts. The wattage input levels at which the lamps were operated resulted in minimum cold spot temperatures of about 600° C, and the specified doses are sufficient to assure an unvaporized excess of metal halide, that is LiI liquid in which are dissolved TII and ZnI_2 .

TABLE II

amp No.	Dose mg/cc	INPUT			Radiation:		Watts Red	Red Eff.
		Watts	Volts	Amps	Blue	Green		
1	LiI 3.8	400	67	7.2	1.8	—	13.1	3.3%
2	LiI 1.33 TII 1.33	400	77	6.8	1.4	10.0	8.5	2.1%
3	LiI InI_3	400	94	5.3	24.0	—	11.3	3.3%
4	LiI 1.67 TII 1.67 ZnI_2 .83	400	101	5.1	9.0	15.0	17.5	4.4%
5	LiI 1.67 TII 1.67 ZnI_2 .83 Hg .83	350	125	3.5	9.2	15.6	17.0	4.9%
5X	LiI .57 TII .91 ZnI_2 .63 Hg .06	1450	320	4.4	25	55	55	4.2%

as threefold. There is substantially no characteristic mercury radiation present in either the visible or the ultraviolet, and the volt ampere characteristic of the lamp remains substantially unchanged. This level of mercury is advantageous in lamps wherein it is desired to exclude all line radiation of mercury from the spectrum.

Where mercury line radiation is not objectionable, a larger quantity of mercury may be added up to about 1 mg/cc. Because the ionization potential of mercury is substantially higher than that of zinc, the ZnI_2 will still control the voltage gradient. However the mercury will decrease thermal losses to the wall and increase the lifetime of charge carriers. This means improved lamp power factor, lower current, and lower electrode losses at the same power input.

ADVANTAGES OF METAL HALIDE BUFFER SPECIES

The effects and advantages of including a metal hal-

The unexpected advantages achieved in accordance with our invention by adding ZnI_2 as a buffer to a lamp containing LiI and TII are apparent upon comparison of lamps Nos. 1, 2 and 3 not containing ZnI_2 with lamps Nos. 4, 5 and 5X having an addition of ZnI_2 within the stated limits.

Lamps Nos. 1, 2 and 3

Lamp No. 1 containing only LiI emits in the red band but has the characteristically low voltage of a nonthermal discharge and requires a high operating current to produce substantial red radiation. The high operating current results in large electrode losses and consequently low power input to the arc itself, the efficiency in producing red radiation being only about 3.3%.

Lamp No. 2 containing LiI and TII, both emitter species, shows slightly improved electrical characteristics, namely higher voltage and lower current resulting in lower electrode losses. The improved electrical charac-

teristics are due to the fact that TII with a figure of merit of 1 can act as a buffer for LiI whose figure of merit is 7×10^{-5} . However a decrease in red radiation and a drop in red efficiency to 2.1% results because the discharge is now tending towards a thermal arc and the electron temperature has decreased.

Lamp No. 3 contains InI_3 which has a figure of merit of 450 and is a relatively good buffer. Its addition to the lithium iodide discharge raises the voltage gradient substantially and reduces the electrode losses. Indium is a strong blue emitter and due to its low ionization and excitation potential, it tends to dominate any discharge into which it is introduced. The low ionization potential of indium produces a fairly low electron temperature so that the red radiation of the lithium does not increase as much as might be expected by reason of the improved electrical characteristics of the arc.

If the indium iodide content were reduced to provide the desired blue to red ratio of approximately 1 to 2, the arc voltage would revert very nearly to that of Lamp No. 1 containing only LiI. Thus InI_3 cannot effectively be used as a buffer with LiI for the present purpose, and it is virtually relegated to an emitter species. Lamps Nos. 4, 5 and 5X

Increase in Red and Green Radiation

In these lamps, the unexpected effectiveness of ZnI_2 serving as a buffer to increase the characteristic radiant output of the lithium and thallium present is immediately apparent. Considering the red efficiency from lithium iodide in lamp No. 4, it is increased to 4.4% which is more than double the red efficiency in lamp No. 2 using the same emitter species LiI and TII but without the ZnI_2 buffer species. Considering the green efficiency from thallium iodide, it is increased to 15% by comparison with 10% in lamp No. 2, an increase of 50%. The same startling increase in the red efficiency resulting from lithium radiation and in the green efficiency resulting from thallium radiation is observed in lamps Nos. 5 and 5X both of which contain ZnI_2 .

Blue Radiation

When ZnI_2 is used as a buffer, its high ionization potential insures that it will not produce radiation which will dominate the spectral output. Therefore the quantity can be adjusted to achieve the desired electrical and thermal characteristics and at the same time to produce the desired blue radiation by the characteristic emission of zinc in the blue spectral band.

Lithium Depletion

Another unexpected benefit from the presence of ZnI_2 is its ability to prevent chemical attack of the quartz arc tube by the lithium. Lithium is the lightest of the alkali metals and when lithium iodide is used alone in a quartz arc tube, it tends to become depleted rapidly, possibly by diffusion of lithium through the quartz. The presence of ZnI_2 provides a chemical protective effect which greatly reduces the rate of loss of LiI and extends the useful life of the lamp as much as a hundredfold, from a few hours to a thousand hours or more.

Coincidence of Colors in Arc

A desirable feature of the lamps according to the invention is the physical coincidence of the red, green and blue colors in the arc. In the usual metal halide lamps containing mercury and various metal halide additives, the core of the arc is generally surrounded by a reddish sheath of larger diameter. This means that the red radiation cannot be focused in exactly the same

way as the other radiation and this fact introduces serious problems in reprographic applications. This shortcoming is eliminated by the use of ZnI_2 combined with LiI and TII according to the invention.

Mercury Addition Less Than 0.25 mg/cc

In lamps Nos. 5 and 5X, some mercury is added. In lamp No. 5X wherein the added mercury is less than 0.25 mg/cc, the effect is to reduce the reignition voltage without producing any mercury radiation, either in the visible or in the ultraviolet. The substantially complete elimination of mercury radiation is a desirable characteristic for certain lamp applications.

Mercury Addition Less Than 1 mg/cc

In lamp No. 5 containing a larger amount of mercury but not exceeding 1 mg/cc, mercury serves as a secondary buffer backing up ZnI_2 as primary buffer and the lamp characteristics are further improved. The ionization potential of mercury is substantially higher than that of zinc so that at the limited mercury vapor pressures achieved, ZnI_2 still controls the voltage gradient. However the mercury decreases the thermal losses to the wall and increases the lifetime of charge carriers. This results in improved lamp power factor, namely lower current at the same power input resulting in lower electrode losses. Thus, comparing lamps Nos. 4 and 5, the latter achieves substantially the same spectral output only at a lower power input and at higher efficiency. The loading or input wattage to lamp No. 5 has been reduced 10% by comparison with lamp No. 4, but the decreased thermal losses has improved the red radiation efficiency by 10% and the spectral output is undiminished. The presence of mercury in lamp No. 5 does not cause any appreciable radiation in the visible but it does cause some ultraviolet mercury radiation.

Overall Efficiency

When lamp No. 5 containing ZnI_2 as a buffer and a limited quantity of mercury is compared to lamp No. 2 containing only the emitter species LiI and TII, the useful output is 2.3 times greater overall and is approximately balanced in the desired 1:2:2 ratio as between blue, green and red. The vapor pressure at 350 watts input with 600° C cold spot temperature are ZnI_2 , 30 to 50 torr; TII, 7 to 15 torr; and LiI, 0.04 to 0.1 torr.

Taking lamp No. 5 as typical of lamps according to the invention which include ZnI_2 as buffer species and LiI and TII as emitter species, the radiant output in the selected bands is more than doubled. The spectral output of this lamp is shown in FIG. 2 from which the concentration of radiation within the selected bands and the low level outside of these bands is apparent. With an input of 350 watts the radiation in the selected blue, green and red spectral bands is 42 watts for an efficiency of 12%. This is a high level of efficiency for a specialized lamp, and several times higher than the efficiency achieved by the use of multiple light beams with filters.

Considering the overall efficiency of lamp No. 5 within the visible range extending from 4,000 Å to 7,000 Å. with an input of 350 watts the output radiation is 70 watts for an overall efficiency of 20%. By comparison, in a conventional high pressure mercury vapor lamp having an input of 350 watts, the radiation in the visible range is 57.5 watts for an overall efficiency of 16.5%. Thus the overall efficiency within the visible range of lamp No. 5 exceeds that of the conventional mercury vapor lamp by better than 20%.

OTHER EMBODIMENTS

The characteristics of other lamps embodying the invention and using different metal halide buffer and emitter species are given in Table III below. For ease of identification the buffers have been listed in a column separate from the emitters. The number in parentheses following the chemical compound is the weight in milligrams provided in a lamp having approximately the same physical dimensions as the lamp previously described and illustrated in FIG. 1.

TABLE III

Lamp No.	Dose (mg)		INPUT			Radiation: Watts		
	Buffer	Emitter	Watts	Volts	Amps	Blue	Green	Red
5A	ZnI ₂ (5), Hg(5)	LiI(10), TlI(10)	300	127	3.1	6.4	12.1	12.1
6	CdI ₂ (10)	LiI(10), TlI(10)	300	110	4.1	5.4	11.8	12.4
7	SbI ₃ (5)	LiI(10), TlI(10)	300	168	2.5	3.7	9.9	9.0
8	PbI ₂ (10)	LiI(10), TlI(10)	300	98	4.2	2.7	7.8	6.9
9	Se(5), Hg(5)	LiI(10), TlI(10)	300	142	2.7	2.2	13.7	10.1
10	AsI ₃ , Hg(5)	LiI(10), TlI(10)	300	165	2.2	3.6	12.2	11.4

Lamp No. 5A is the same as lamp No. 5, the preferred embodiment previously given in Table II, only operated at 300 watts instead of 350 in order to permit direct comparison. In lamps Nos. 6 through 10, the emitters are lithium iodide and thallium iodide, and the emitter dosage is the same as in lamp No. 5; however different buffers selected from Table I are used with the results indicated.

It will be observed that in lamps Nos. 6 through 10, at least one of the blue, green or red radiation bands of the lithium or thallium is considerably enhanced by comparison with lamp No. 2 containing only lithium iodide and thallium iodide emitters without buffers. However, the relative output in the blue, green, and red bands are no longer approximately in the 1:2:2 ratio in every case. Thus the various combinations of Table III may be used where lamps having other spectral charac-

teristics are required.
What we claim as new and desire to secure by Letters Patent of the United States is:
1. A high intensity lamp providing radiation concentrated in selected spectral bands comprising:
an hermetically sealed light-transmissive envelope;
a pair of arc electrodes sealed therein and defining an arc gap;
an inert starting gas at a pressure of a few torr therein;

and a charge therein comprising per cubic centimeter of envelope volume from about .02 to 2.0 milligrams of LiI, from about .02 to 1.5 milligrams of ZnI₂, and from about .02 to 3.0 milligrams of TlI.
2. A lamp as in claim 1 containing in addition not over about 0.25 milligrams of mercury per cubic centimeter of envelope volume.
3. A lamp as in claim 1 containing in addition not over about 1 milligram of mercury per cubic centimeter of envelope volume.
4. A lamp as in claim 1 wherein the electrodes consist of unactivated tungsten.
5. A lamp as in claim 1 containing per cubic centimeter of envelope volume about .57 mg. of LiI, about .91 mg. of TlI, about .63 mg. of ZnI₂ and in addition about .06 mg. of Hg.

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