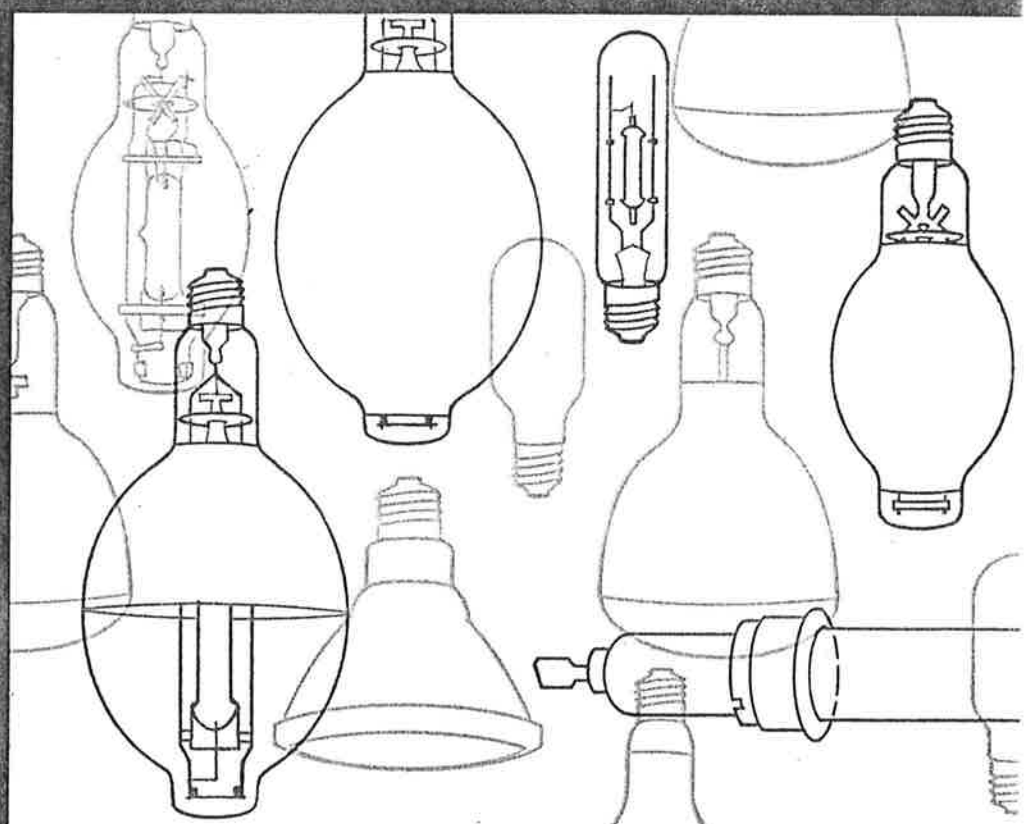
1962

mercury

LAMPS

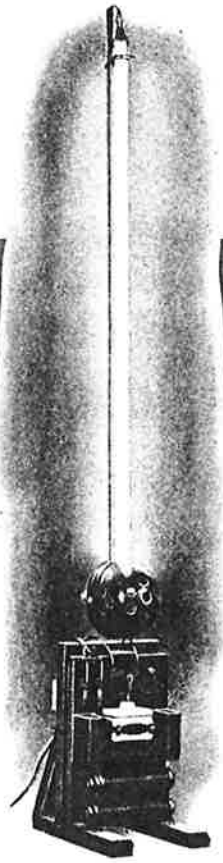


TP-109

LARGE LAMP DEPARTMENT

GENERAL ELECTRIC

Mercury Lamps



Peter Cooper Hewitt's first mercury lamp looked a lot different from lamps in today's mercury lamp line. The Cooper-Hewitt lamp was about 4 feet long, and it produced bluish-green light.

MERCURY lamps combine the relatively small size of incandescent lamps with the long life and high efficiency characteristics of fluorescent lamps. These high-wattage light sources produce a considerable amount of light for their size. As a result, mercury lamps offer many advantages to the user, particularly in industrial, street lighting, floodlighting, and other outdoor commercial applications.

Mercury lamps are "electric discharge" lamps. As such, they produce light by passing a current through a gas vapor under pressure rather than by heating a filament as in incandescent lamps.

Although the first high-pressure mercury lamp was not introduced until 1934, the first mercury vapor lamp was developed in 1901 by Peter Cooper Hewitt. Known as the Cooper Hewitt lamp, it was approximately 4 feet long and produced bluish-green light. In 1919 the Cooper Hewitt Company became part of the General Electric Company, and later was known as the General Electric Vapor Lamp Company.

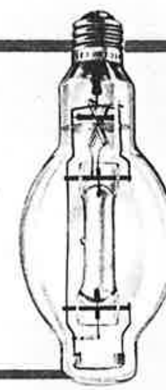
The mercury lamp, as it is known today, was first introduced in the 400-watt size with a glass arc tube. Later, other lamps were added, and today the line of general lighting mercury lamps ranges from 100 to 3000 watts.

The introduction of the quartz arc tube in the 400-watt size increased output about a third for the same wattage. Originally the several sizes of quartz arc-tube mercury lamps were introduced in tubular bulbs; however, today the bulbs for most lamps for general lighting applications are BT (bulged-tubular) or R (reflector) bulbs.

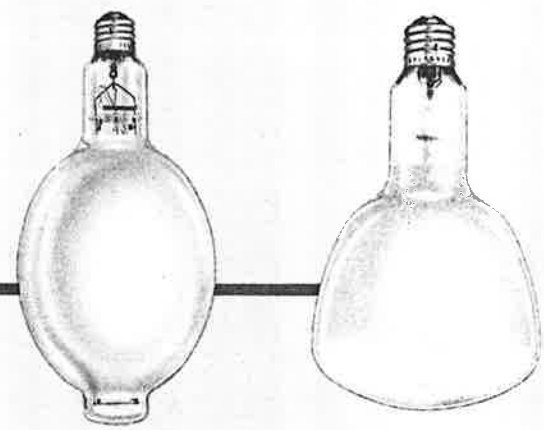
In recent years, several significant improvements in mercury lamp performance have been introduced.

The development of color-improved and white phosphor-coated lamps added versatility in light output and color rendition with mercury lamps.

The first practical commercial 400-watt mercury lamp was tubular in shape. G-E still manufactures tubular mercury lamps for replacement purposes. Tubular mercury lamps today are manufactured with quartz arc tubes.



The H400A33-1 is one of today's most popular mercury lamps. This 400-watt clear lamp is representative of modern bulged-tubular lamps. Clear lamps are used when light output control is necessary, and where some sacrifice in color rendition is tolerable.

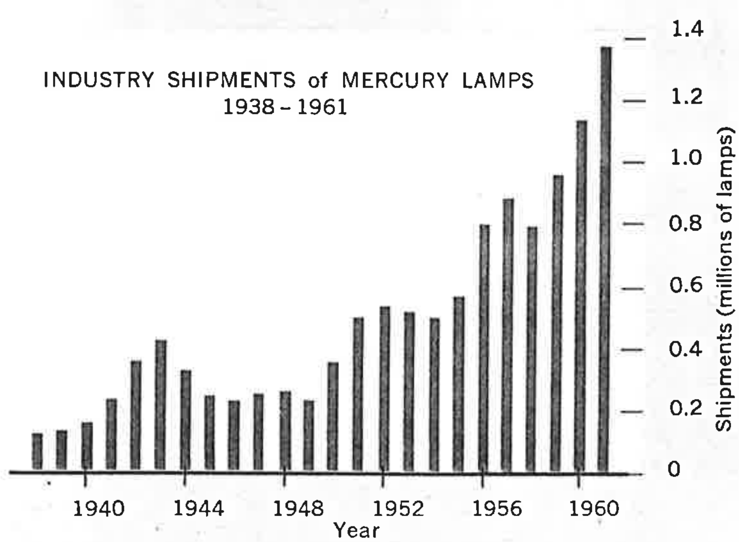


Mercury lamps are available in color-improved, white, deluxe, and yellow types, as well as clear. Color rendition is improved by coating the inside of the lamp with phosphor; the deluxe lamp is inside-coated and outside-stained. Shown here are examples of inside-coated mercury lamps.

In 1958, G-E introduced the 400-watt Bonus Line design in this country. This design greatly improved maintenance, lengthened useful life, and improved low-temperature starting characteristics. In 1961, G-E led the industry in standardizing on the Bonus Line design in all mercury lamps.

Improvements in the design of the arc tube, the heart of the mercury lamp, have increased life to the point today where there is no exact value that represents average life in the varied applications encountered.

Today's 400-watt clear mercury lamp is rated at 20,500 lumens, average life in excess of 16,000 hours, and 92% mean lumens over 16,000 hours. In comparison, ten years ago the 400-watt clear lamp was rated at 20,000 lumens, 3000 hours life, and 83% mean lumens over 3000 hours. Light output of today's lamp is as high at 12,000 hours as light output of the 1952 lamp was at about 1000 hours.



Mercury lamp shipments have increased from slightly over a hundred thousand in 1938 to nearly a million and a half in 1961.

Mercury Lamp Parts

Nearly all mercury lamps today consist of an arc tube enclosed within an outer tube (bulb), plus supplementary parts. The arc tube contains the essential operating components — electrodes, mercury vapor, and argon gas. The outer bulb maintains nearly constant arc tube temperature, and protects the arc tube and internal parts from the atmosphere.

BASE — Connects lamp to electric circuit and permits easy lamp replacement. Bases are made of brass, and are mogul in most mercury lamp types. Using mechanical bases assures maximum base strength even at high temperatures, because there is no cement to bake out. Imprinted letters and numbers on the base can be used to record the date of installation, showing the long service rendered by G-E mercury lamps. The lower wattage mercury lamps for special applications use admedium or medium screw bases.

HEAT DEFLECTOR — Reduces the flow of hot gases from near the arc tube into the neck of the outer bulb. Thus it protects the base and socket from excessive heat. Made of polished nickel-plated iron, the heat deflector also reflects light which would otherwise be wasted in the base.

ARC TUBE — Confines mercury arc and withstands high temperature when the lamp is operating. This tube contains a precise quantity of mercury and a small amount of pure argon gas. The main and starting electrodes are sealed at each end. The heart of the mercury lamp, the arc tube, is made of pure quartz. The end of the arc tube is platinum-coated to insure reliable warm-up at low temperatures.

MAIN ELECTRODES — Act as terminals for the main arc. On each half-cycle, one main electrode acts as the anode, the other as the cathode. The electrodes change functions each time polarity of the supply changes. Each electrode is a double layer of tungsten wire, embedded with rare earth oxides. This electrode design is the key to the Bonus Line design. The electrodes are connected through the arc tube seals by molybdenum foil leads.

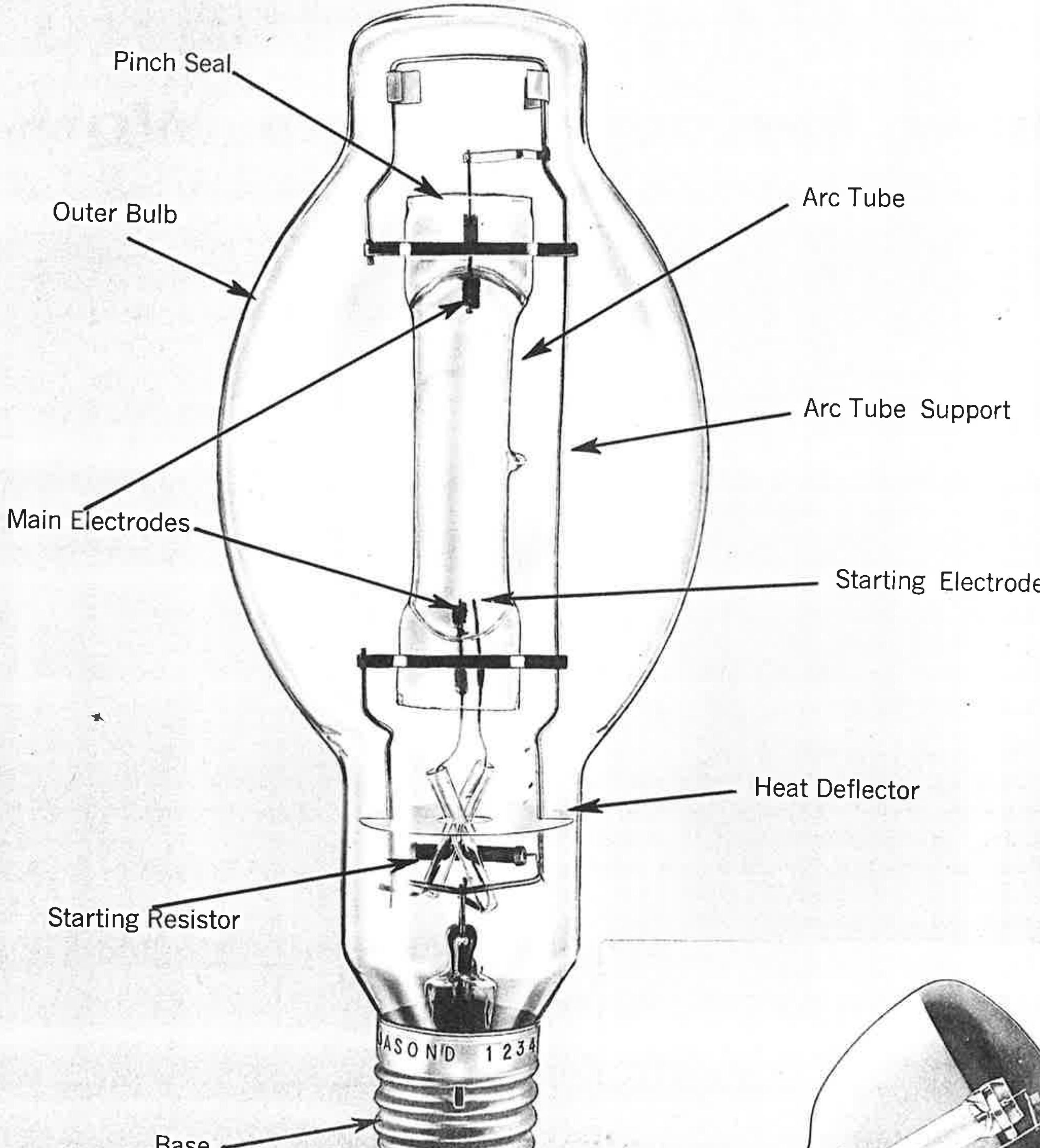
PINCH SEAL — Keeps mercury and argon gas in the arc tube, and nitrogen (used between the arc tube and outer tube) out. This seal is largely responsible for today's increased lamp life.

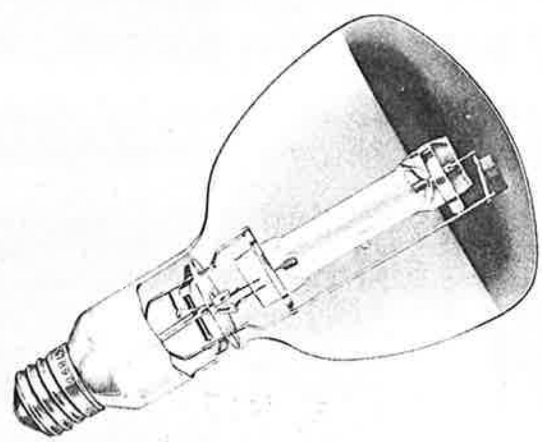
OUTER BULB — Maintains nearly constant arc tube temperature. Efficient operation depends on high arc tube temperature; the outer bulb minimizes cooling by air circulation and reduces the influence of ambient temperature on arc tube temperature. Usually made of heat-resistant glass, the outer bulb protects inner parts and filters ultraviolet. Also, it can be phosphor-coated. Because the outer bulb is made of weather-resistant glass, a mercury lamp can be used in directly exposed outdoor applications.

ARC TUBE SUPPORT — Holds arc tube in place, and conducts electricity to the far main electrode. Made of polished metal to reduce light absorption. Also, the size is minimized to reduce absorption of light. Although small in size, the arc tube mount withstands shock and vibration encountered in service. The 400-watt BT-37 lamps have been subjected to shocks of over 40 G's without damage.

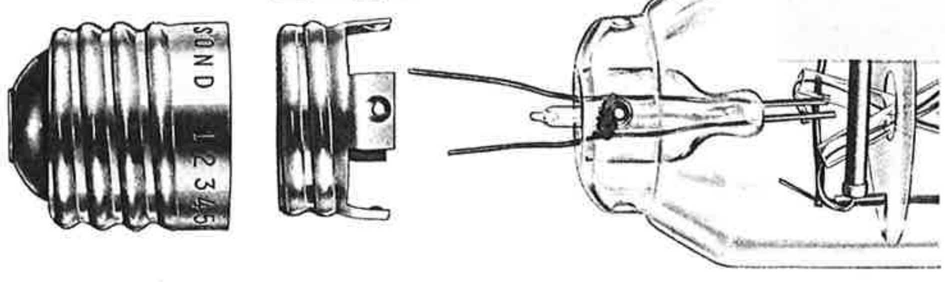
STARTING ELECTRODE—Strikes arc to closest main electrode when power is initially applied. This arc ionizes the argon in the arc tube, and aids in striking of the main arc.

STARTING RESISTOR — Limits current to the starting electrode to a low value. The starting resistor is designed to withstand high-temperature conditions present in a mercury lamp.





Mechanical Base



How Mercury Lamps Work

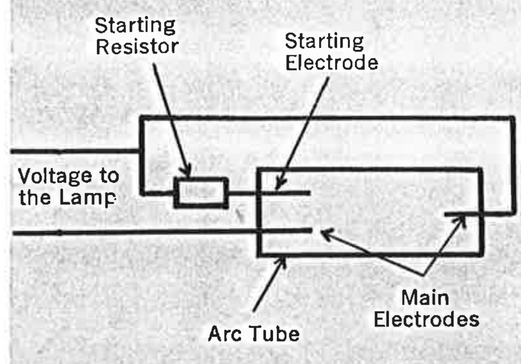
Mercury lamps are classified as high-pressure mercury vapor lamps, contrasted with fluorescent lamps which are low-pressure mercury vapor lamps. The lower mercury vapor pressure in fluorescent lamps results in the arc radiating most of its energy in the ultraviolet region, which in turn energizes the phosphors in fluorescent lamps to produce light. With the higher pressure present in a mercury lamp, the arc produces visible light directly.

Mercury lamps have a negative resistance characteristic; —thus a ballast to limit current is required. Besides limiting lamp current to the proper value, the ballast also supplies the necessary starting voltage if line voltage is not adequate.

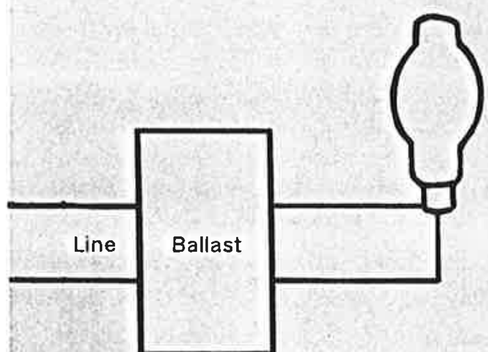
The arc tube contains a small amount of pure argon gas to aid in starting the lamp. When voltage is first applied to the lamp, a small arc strikes in the argon gas between the starting electrode and the nearby main electrode. This arc ionizes the argon gas. The ionized gas spreads throughout the arc tube, almost instantaneously, and, an arc strikes between the main electrodes.

The starting resistor, usually 40,000 ohms, performs two functions: 1. It limits current in the starting arc. (After the main arc strikes, current to the starting electrode is about 1/1000 of current in the main arc.) 2. It creates a higher resistance path for the starting arc than for the main arc. (Without this higher resistance path, the main arc could not strike.)

After the main arc strikes, heat from the main arc vaporizes the remaining liquid mercury. Each main electrode acts alternately as cathode and anode as polarity reverses each half cycle. As more and more of the mercury vaporizes, the voltage across the lamp terminals rises until all of the mercury is vaporized. Lamp voltage then remains constant.



Electrical details of the mercury lamp. The starting resistor, located within the lamp, limits starting current, and creates a higher resistance path for the starting arc than for the main arc.

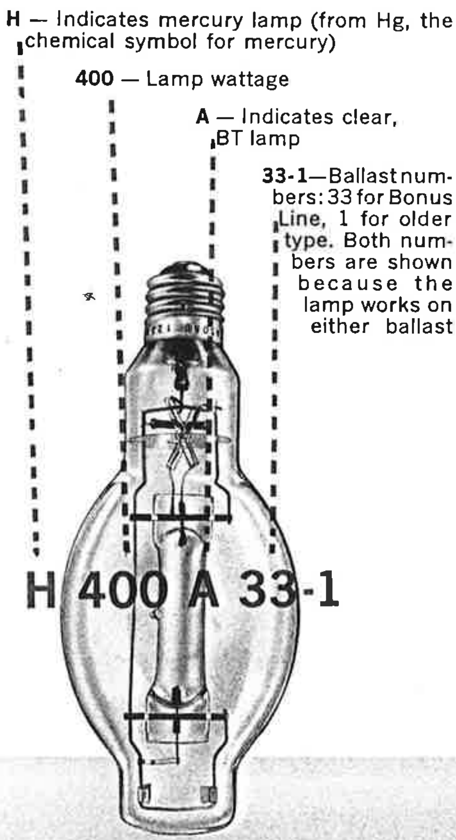


Basic mercury lamp circuit. The ballast limits lamp current, and also steps up primary (line) voltage if it is not sufficient to start the lamp reliably.

Designations

G-E mercury lamps are identified by a meaningful designation system which is designed to describe the lamps. Some time ago, the American Standards Association adopted a designation system so that similar lamps of various manufacturers would have the same designations. All G-E mercury lamps are assigned ASA codes. Both the G-E and ASA codes are shown in lamp schedules and on lamp carton labels. Lamps can be ordered by either code; however, the G-E code is recommended.

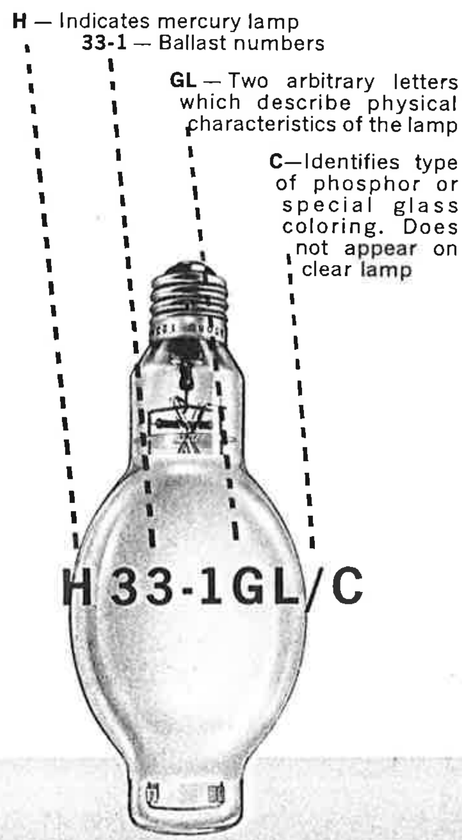
G-E System



Other Letters

C — Color-improved phosphor
W — White phosphor
R — Reflector bulb
PFL — PAR floodlight
PSP — PAR spotlight
Y — Yellow
CX — Deluxe
BL — Black light filter
RFL—Reflector flood
RSP—Reflector spot
RCFL—Color improved reflector flood
/T — Tubular bulb

ASA System



Other Letters

Unlike the G-E system, the ASA system uses two arbitrary letters to designate lamp characteristics. For example, CD is used with a clear BT-37 bulb with mogul screw base, such as the clear 400-watt lamp. If the bulb is phosphor-coated, the designation changes from CD to GL. An additional letter is necessary to identify the type of phosphor coating.

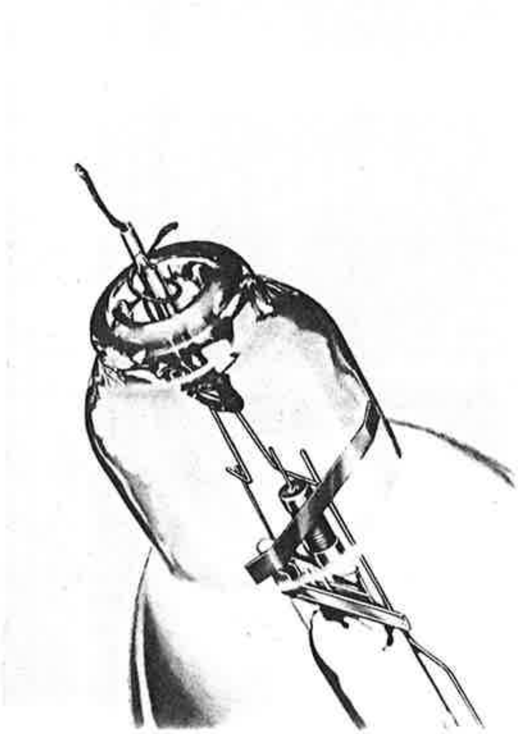
General Classes of Mercury Lamps

Mercury lamps for general applications are available from 100 to 3000 watts. The 175 and 400-watt sizes are by far the most widely used mercury lamps. While an exact separation of the various mercury lamps by application is not possible, it is possible to describe generally the applications for the several wattage classifications.

SIZE	APPLICATION NOTES
85 and 100-watt (T-10 bulbs)	Used in specialized laboratory and optical equipment.
100-watt (PAR-38 bulb)	Used for building and landscape floodlighting and with red-purple ultraviolet filter for black-light applications. Available with either spot or flood distribution.
100-watt (T-16 black light bulb)	For black-light applications.
100, 175, and 250-watt (BT bulbs)	General lighting – residential and secondary street lighting, floodlighting. Clear lamp used with filter in black-light applications.
400-watt (BT bulb)	General lighting—industrial, street and floodlighting.
400-watt (R-52 bulb)	General lighting – industrial applications.
400-watt (T-16 bulb)	General lighting – street lighting. Used for replacement in fixtures which will not accommodate BT-37 bulb.
400-watt (R-60 bulb)	Floodlighting
700-watt	General lighting – street, industrial and flood.
1000-watt*	General lighting – street, industrial and flood.
1500-watt	All-quartz, 12-inch lighted-length linear lamp for specialized applications. In floodlighting applications, fixtures should be enclosed to filter ultraviolet.
3000-watt	55-inch lamp yields 132,000 lumens. Used in high-mounting industrial applications.

*There are two different types of 1000-watt lamps. One is a high-voltage, low current design (H36-15), the other is a low-voltage, high-current design (H34-12). The H36-15 lamps can operate from 480-volt circuits with only a choke as a ballast. The H34-12 lamps can operate from 240-volt circuits, in a similar manner.

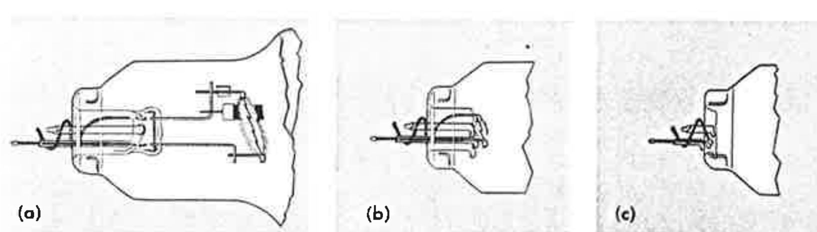
Street Series Mercury Lamps

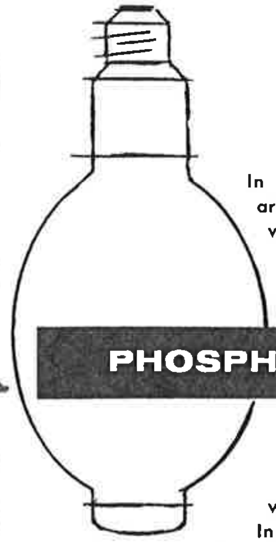


In some street lighting installations, 400-watt Mercury lamps are operated on 3.2-ampere series circuits with a regulator and no individual ballasts. In these installations, premature failure of the film cut-outs due to voltage surges can result. The G-E street series 400-watt lamp, identified by 3.2A at the end of the ordering code, includes an internal cut-out which eliminates the need for the film cut-out. It protects the socket, and yet allows the lamp to accept voltage surges not high enough to damage it.

HOW THE INTERNAL CUTOUT WORKS:

One of the lead-in wires is enclosed in a special glass sleeve; the other wire is wrapped around this sleeve. When the lamp burns out, (a) an arc forms between the lead-in wires; (b) the arc travels into the glass sleeve and melts it; (c) the special sleeve enables the the lead-in wires to fuse together, completing the circuit and extinguishing the arc before it reaches the socket.



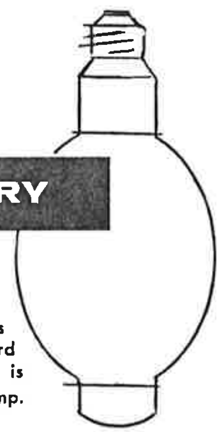


In addition to the visible light, the mercury arc produces significant quantities of ultraviolet energy. This energy can be used to improve color rendition or efficiency by coating the inside of the bulb with phosphor.

PHOSPHOR-COATED

Color-improved lamps use a phosphor strong in red energy; significantly improved color rendition is thus achieved with a small sacrifice in efficiency. In "white" lamps, the phosphor produces energy throughout the visible band, increasing efficiency about 7%. Although color rendition of the white lamp is better than the clear version, it is not as good as the color improved lamp.

In semi-reflector lamps, phosphor is used both as a reflector and a producer of light. About 2/3 of the light is directed away from the lamp base and about 1/3 toward the base.
Result: Better maintenance characteristics.



YELLOW MERCURY

A 400-watt yellow mercury lamp is available for use in applications where a "caution" atmosphere is desired, such as at dangerous intersections. The color is close to the standard caution color of traffic signals. Light output is about 40% lower than the color-improved lamp.

H-6 MERCURY LAMPS

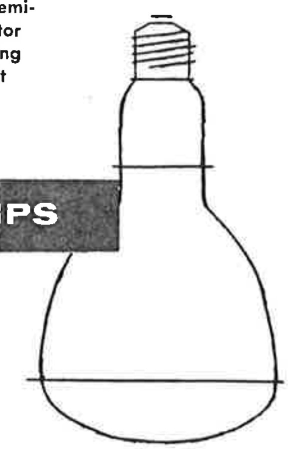
Two compact 1000-watt mercury lamps for special applications are available from the G-E Outdoor Lighting Dept., Hendersonville, N. C. These lamps are cooled by compressed air (B-H6) or water (A-H6) because of extremely high operating temperature. Brightnesses up to 195,000 candles per square inch can be obtained with the A-H6 lamp.

BLACK LIGHT

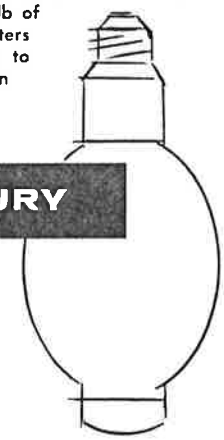
Mercury lamps produce a significant amount of near ultraviolet energy during operation. Thus, they can be used as sources of "black" light. If desired, the visible light can be removed by using suitable filters. A 100-watt mercury lamp built specifically for black light applications has an outer bulb made of filter glass.

Reflector and phosphor coated semi-reflector mercury lamps provide built-in light control. With the reflector sealed inside the lamp, the loss of light during life as a result of dirt is minimized. 400-watt R-52 reflector and semi-reflector lamps and 1000-watt semi-reflector lamps are widely used in high mounting industrial lighting applications. 400-watt R-60 and 100-watt PAR 38 lamps are used in floodlighting installations.

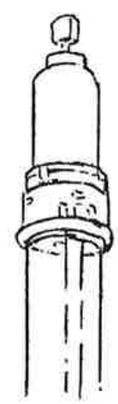
REFLECTOR LAMPS



In some mercury lamp applications, a greater degree of color-improvement is desired. A Deluxe Mercury lamp is available in the 400-watt, BT-37 type. Improvement in color rendition is achieved through the use of a purple stain on the bulb of a regular color-improved lamp. This stain filters out some of the green and yellow energy to improve color rendition. This reduction in energy reduces lamp efficiency over 25% compared to the color-improved lamp.

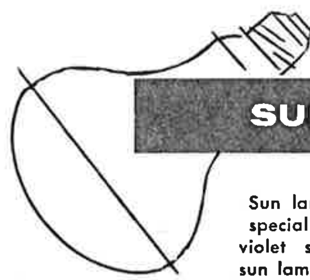


DE LUXE MERCURY



ULTRAVIOLET

A number of tubular mercury lamps are available for special ultraviolet applications. These lamps range in size from 85 to 10,000 watts, and are used in printing, weathering tests, photographic applications, etc. A new T-3 quartz lamp group is being developed for newer printing techniques.

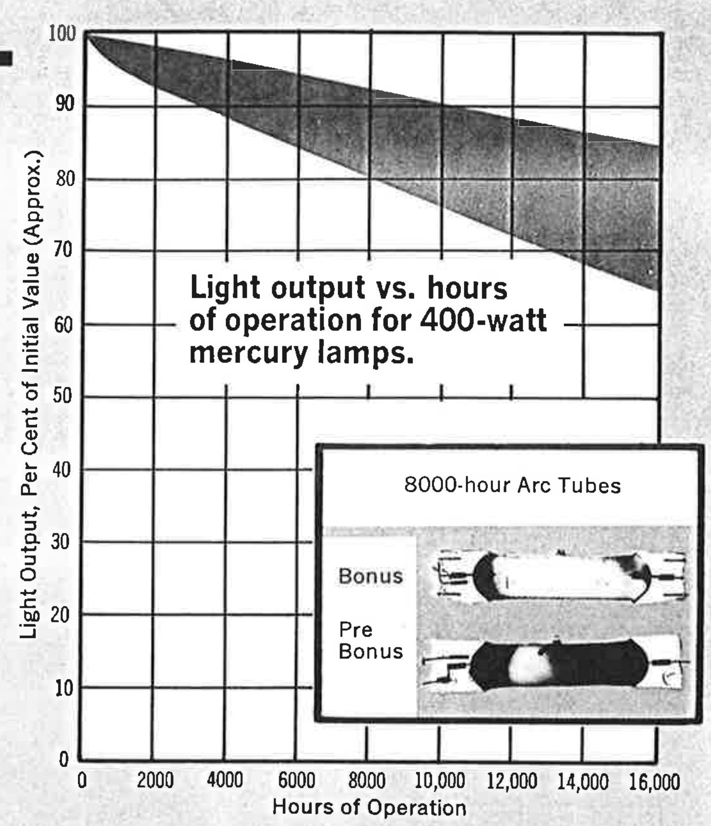


SUN LAMPS

Sun lamps are regular mercury lamps with special bulbs to transmit the middle ultraviolet sun-tan radiation. The RS reflector sun lamp, by far the most popular sun lamp, has a built-in starting switch and a 175-watt filament ballast. Thus it requires only a holder with a medium base socket. Sun lamps must be used according to directions.

Maintenance

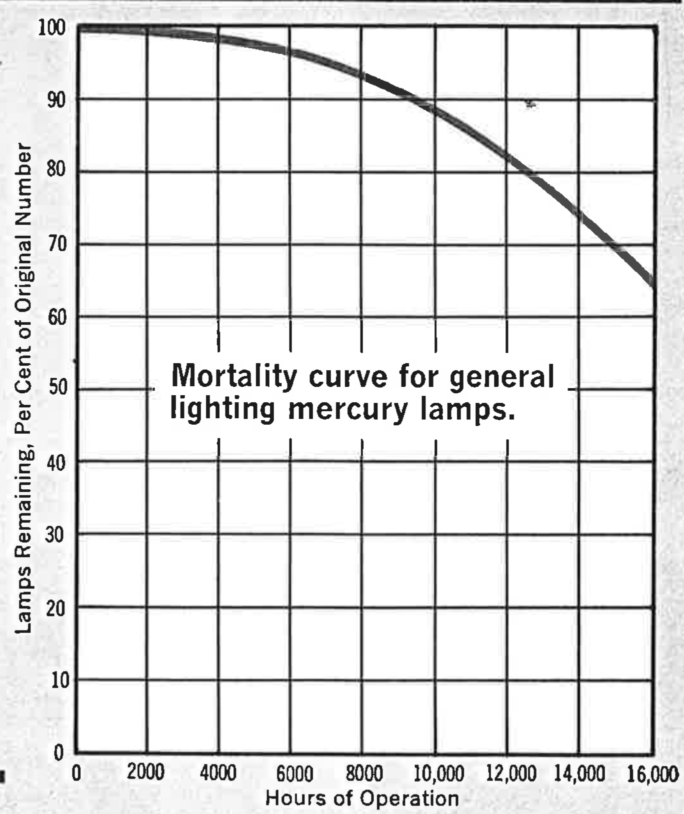
Like other light sources, light output of mercury lamps depreciates throughout life. The most significant feature of Bonus Line lamps is the great improvement in light output depreciation. The pictures (right) show a Bonus Line and a pre-Bonus Line arc tube photographed after 8000 hours of operation. In the older design, the arc tube blackened severely over the life of the lamp. However, only a white deposit develops at the arc tube ends in Bonus Line lamps. Result: A significant improvement in lumen depreciation. For example, the 400-watt clear Bonus Line lamp produces as much light at 16,000 hours as the clear 400-watt lamp it superseded produced at 3500 hours. This improvement in maintenance has greatly extended the useful life of mercury lamps.



Mortality

Long life is one of the performance features of mercury lamps. All general lighting mercury lamps today have an average life in excess of 16,000 hours. Development of the Bonus Line design and improvements in arc tube construction have greatly increased lamp life.

The typical mortality curve for general lighting quartz arc tube mercury lamps is shown at the right. The actual life in service depends largely on operating conditions. The published ratings are based on an operating cycle of 5 or more hours per start; shorter burning intervals shorten lamp life. Other operating conditions such as excessively high ambient temperature, ballast design and line voltage may also affect lamp life.



Group Relamping

Mercury lamps can be group relamped, but since lamp costs are a high proportion of the total cost of replacement, group relamping of mercury installations is not widely practiced, except in street lighting. Group relamping of mercury lamps in hard-to-reach locations may also be practical.

Auxiliary Equipment

With a negative resistance characteristic, a mercury lamp requires a current-limiting device, generally called a ballast, to operate properly. In addition to operating the lamp at the proper wattage, the ballast also produces the proper starting voltage if the line voltage is insufficient.

There are three basic ballasts which are used in mercury lamp circuits: reactor, autotransformer, and stabilizing (sometimes referred to as a regulator or constant-voltage type).

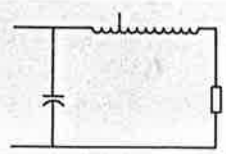
Two-lamp designs are available in all basic circuit types. Reactor and autotransformer two-lamp ballasts of the lead-lag type feature high power-factor operation. Two-lamp stabilizing ballasts often operate the two lamps in series.

Ballast wattage losses usually range from 5 to 10% of the lamp wattage, depending on the ballast and lamp types.

Ballasts must be designed for the voltage and frequency of the line on which they will be used. If the line voltage is too low for the ambient temperature, the lamp may not start, or it may operate with a reduced current. If allowed to remain in this condition for a long period of time, the lamp electrodes may be damaged causing short life and poor lumen depreciation. With line voltage too high, the ballast causes the lamp to operate over-wattage, resulting in overheating and possible short life.

REACTOR Ballast Circuit

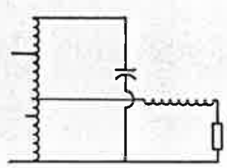
Reactor-type ballasts are in series with the lamp when the line voltage is sufficient for reliable starting. Voltage taps on the ballast match the ballast to the primary (line) voltage. Proper operation is obtained when line voltage is within 5% of a given tap. The reactor ballast is generally the most economical ballast — both in initial cost and operating efficiency, and it is usually the smallest.



Single-lamp

AUTOTRANSFORMER Circuit

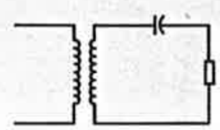
The autotransformer-type ballast incorporates an autotransformer in the ballast to increase the line voltage to the proper value for reliable starting. Line voltage taps match the ballast to the line voltage. Proper lamp and ballast operation is obtained over an input voltage range of plus or minus 5%.



Single-lamp

STABILIZING Ballast Circuit

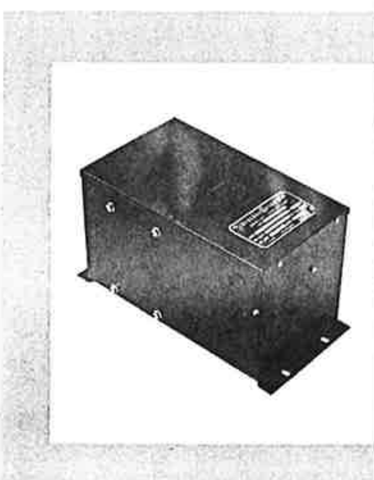
Stabilizing or regulator ballasts consist of a special circuit which improves lamp regulation and lowers drop-out voltage over an extended input voltage range, usually ± 13%. The circuit has a high power-factor. It includes a capacitor in series with the lamp. Because of the regulating characteristics, voltage taps are not needed with this type of ballast. Stabilizing ballasts also require a lower primary current during the lamp starting period; thus they permit a reduction in the cost of wiring.

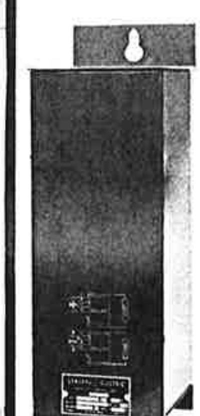


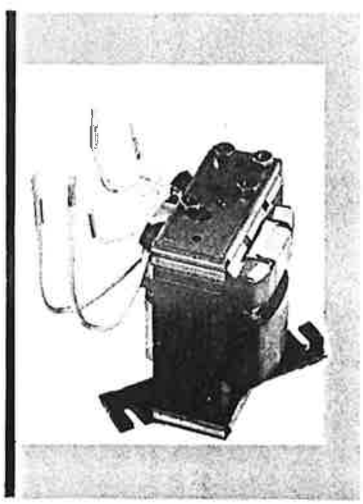
Single-lamp

BALLASTS

From left to right, an enclosed type ballast, weatherproof ballast, and a core and coil construction type ballast. These are representative of the many different types of ballasts available for use with mercury lamps.

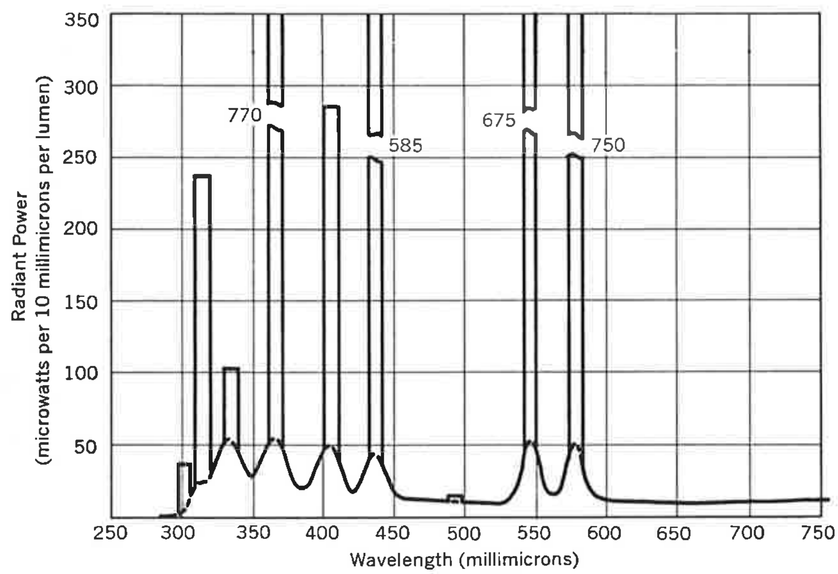




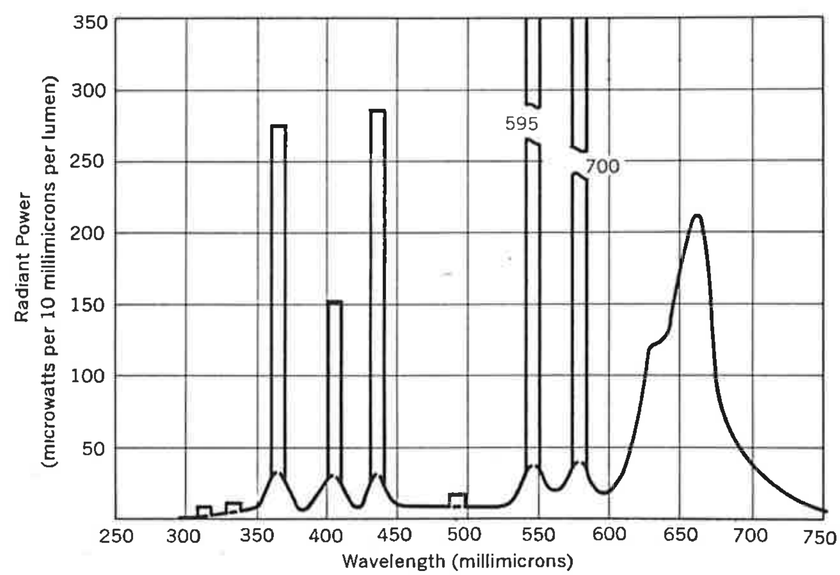


Spectral Data

The spectral distribution of light radiated throughout the spectrum often influences the choice of mercury lamps. The following charts show approximate spectral data for clear, color-improved, white, deluxe, and yellow mercury lamps.

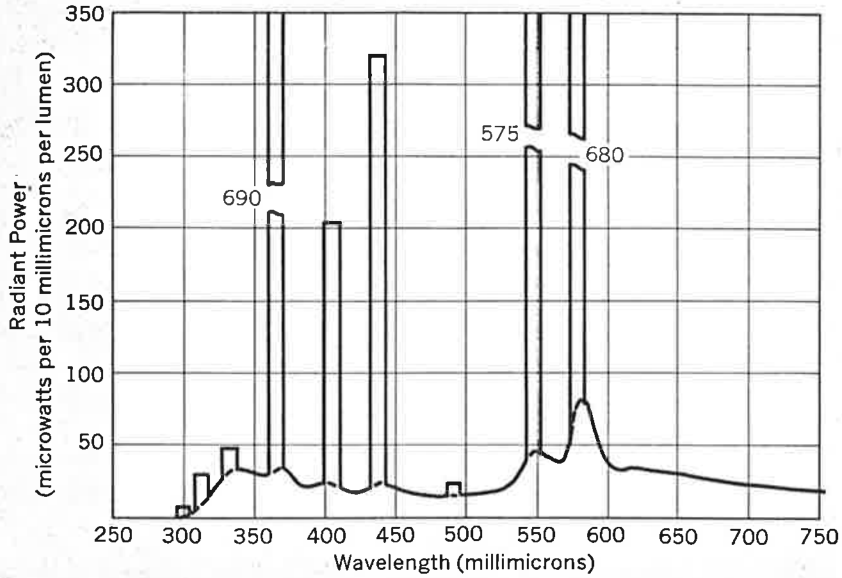


Clear lamp, 400-watt (H400A33-1). Predominant in blue and green, weak in red.

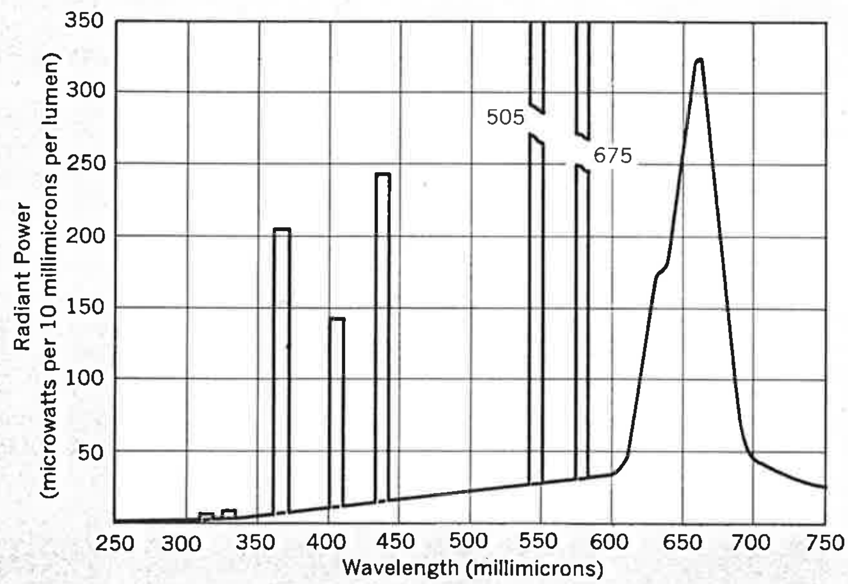


Color - improved lamp, 400-watt (H400C33-1). A phosphor coating inside the lamp improves the color rendition. Light output improvement is in the 600-700 millimicron region.

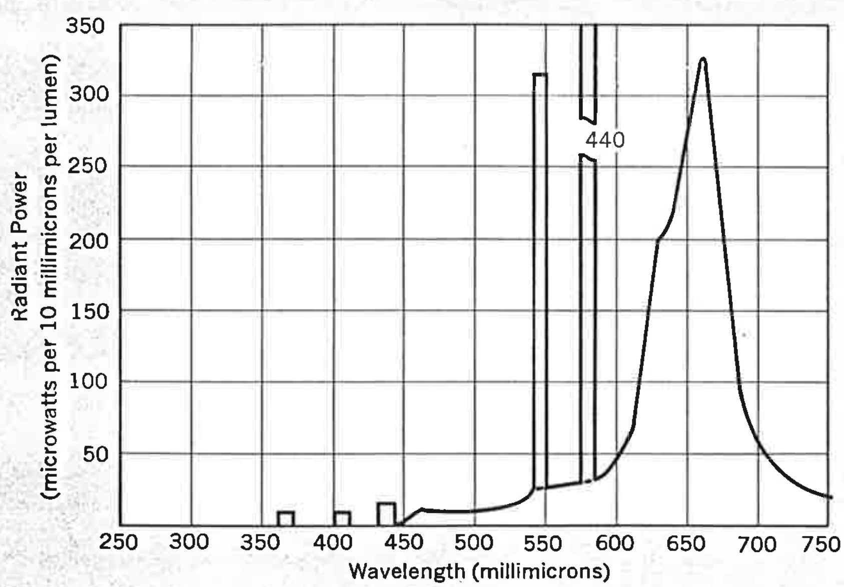
White lamp, 400-watt (H400W33-1). The phosphor coating in this lamp adds light output throughout the visible energy region. Efficiency of this lamp is higher than other types of mercury lamps.



Deluxe mercury lamp, 400-watt (H400CX33-1). In addition to an inside-phosphor coating, this lamp has a purple stain on the outside of the lamp. Color improvement is obtained by filtering out some of the blue and green light to balance light output. Efficiency of the deluxe mercury lamp is about 25% lower than the color-improved mercury lamp.



Yellow mercury lamp, 400-watt (H400Y33-1). A filter on the outside of the lamp reduces light output except for the yellow light. The color of this lamp approximates that of the standard yellow caution light.



Mercury Lamp Light Output

The initial light output rating of mercury lamps is based on the average light output after 100 hours of operation. Lamps are rated for operation in a vertical position (except for the H1500-A23 and H3000-A9) on a reference ballast, as specified by the American Standards Association.

HORIZONTAL OPERATION

Operating a mercury lamp in a horizontal position reduces the light output. Why? Lamp efficiency decreases when the arc floats upward during operation. Separate light output ratings for horizontal operation have been established for many mercury lamps. The horizontal light output rating is based on rated lamp wattage being delivered to the lamp by a reference ballast. The actual output on commercial ballasts depends on the ballast design.

Ballasts are available which are designed to provide the "vertical" light output rating from lamps operated in a horizontal position. This is accomplished by operating lamps over the rated value. Operation under these conditions reduces the margin available for other factors — lamp tolerance, ballast tolerance, primary voltage. Therefore, such operation is not recommended.

On stabilizing type ballasts, lamp wattage in the horizontal position varies with angle of rotation of the lamp. Lamp wattage should be measured at several positions to obtain an average.

OVER-WATTAGE OPERATION

In general, over-wattage operation of mercury lamps is not recommended because of the resulting temperature increase.

In some floodlighting applications with relatively few operating hours per year, obtaining higher light output per lamp at the expense of life and lumen depreciation may be desirable. For such applications, the H1000A36-15 and H1000C36-15 are rated for 1500-watt operation. Initial light output increases almost 50%; however, the rated life decreases to 2000 hours. Light output depreciation increases. Special ballasts are available for 1500-watt operation of these 1000-watt lamps. Loading is high at the increased wattage, and this operation should only be considered with enclosed fixtures—usually with the lamp base down.

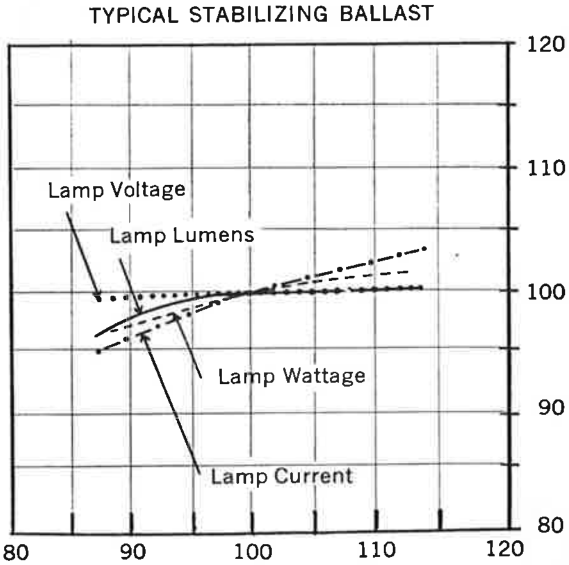
EFFECTS OF POWER INTERRUPTIONS

One of the limitations of the mercury lamp is the effect of power supply interruptions. In the event of a power interruption or voltage dip lasting for more than one cycle, mercury lamps extinguish and do not restart for several minutes. The exact magnitude of the voltage drop to cause this condition depends on the ballast design. Regulator ballasts withstand a greater drop than other types. The delay in lamp restarting is caused by the high pressure which develops in the arc tube during operation. The ballast open circuit voltage is not sufficient to restart the lamp until the lamp cools and the pressure decreases. In installations where this characteristic might be a safety hazard, the use of a few incandescent or fluorescent fixtures along with the mercury units assures emergency illumination until the mercury lamps re-start.

EFFECTS OF VARIATIONS IN LINE VOLTAGE

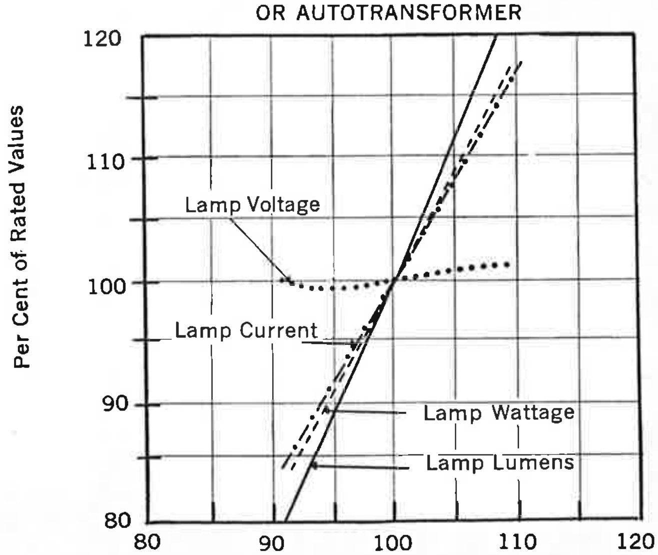
Changes or variations in line voltage can definitely affect the light output of mercury lamps as well as lamp operating current, voltage, and wattage. The curves at left show the effects of voltage changes on a mercury lamp operating on a typical stabilized ballast and a typical reactor ballast. (Operating characteristics on an autotransformer ballast are almost identical to a reactor ballast.)

TYPICAL STABILIZING BALLAST



Per Cent Rated Primary Voltage

TYPICAL REACTOR BALLAST
OR AUTOTRANSFORMER



Per Cent Rated Primary Voltage

and Other Operating Characteristics

OPERATION AT OTHER FREQUENCIES

Mercury lamps have been operated on frequencies as low as 25 cycles with special ballasts. Lamp flicker is noticeable at 25 cycles.

Full performance data of mercury lamps operated at higher frequencies have not been established. No significant advantage in lamp efficiency has been observed. The principal advantage appears to be possible reductions in the size and weight of ballasting equipment.

DIRECT CURRENT OPERATION

Mercury lamps can be operated on direct current. Special ballasting circuits are required. Normal performance ratings do not apply to operation on direct current circuits.

RADIO INTERFERENCE

It is difficult to detect any radio-frequency noise from mercury lamps when they are operating normally. However, a small amount of noise does occur for a few seconds during the starting period.

EFFECTS OF TEMPERATURE

Normally light output of mercury lamps is not affected by low temperatures or cold drafts. However, if an exposed lamp is subjected to low temperature, it may not warm up. This depends on fixture and ballast design. Once the lamp warms up, the outer bulb isolates the internal arc tube from the effects of ambient conditions. The warm-up time of a mercury lamp under cold ambient conditions depends on whether the lamp is enclosed or exposed, as well as on ballast design.

Like other lamp types, mercury lamps have temperature limits for proper operation. For mogul screw general lighting types, the temperature limits are 210C at the base, and 400C on the bulb. Temperature above these limits cause poor performance. The color rendition from a color-improved mercury lamp depreciates as bulb temperature approaches maximum temperature limit.

Higher ballast open-circuit voltage may be required for reliable starting at low temperature; but this increased voltage must not exceed the maximum voltage limitations of the lamp. Most ballasts for outdoor operation are designed to start lamps at temperatures down to −20 F. One of the significant advantages of the Bonus Line design lamps is that they start reliably at −20 F with a well-regulated line voltage of 240 volts and only a choke reactor as a ballast.

LAMP CURRENT WAVE FORM

One of the variables which is affected by ballast design is lamp current crest factor. This is the ratio of peak to RMS current. Too high a current crest factor increases light output depreciation. With Bonus Line mercury lamps, good performance is obtained with crest factors up to 2.0 The current crest factor is measured with the lamp in the vertical position.

LAMP WARM-UP CHARACTERISTICS

During the warm-up of a mercury lamp, light output, lamp current, and lamp watts vary. How these characteristics vary depends on several factors including ballasts, lamp type, line voltage, fixture, ambient temperature, and winds and drafts. The curves below illustrate warm-up characteristics of a mercury lamp operating in 77 F open air on a typical stabilized ballast and a typical reactor ballast. (Lamp operating characteristics on an autotransformer ballast are almost identical to a reactor ballast.)