Sam's and Don's D-Lamp FAQ

Gas Discharge Lamps, Ballasts, and Fixtures

Principles of Operation, Circuits, Troubleshooting, Repair
Version 1.35

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Preface

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DISCLAIMER

We will not be responsible for damage to equipment, your ego, county wide power outages, spontaneously generated mini (or larger) black holes, planetary disruptions, or personal injury or worse that may result from the use of this material.

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Introduction

Gas discharge lamp basics

The use of electrically excited gas discharges significantly predates the invention of the incandescent lamp. Physics labs of yesteryear as well as today have use of a variety of gas filled tubes used for numerous purposes involving light generation including spectroscopy, materials analysis, studies of gas dynamics, and laser pumping. Look through any scientific supply catalog and you will see many different types of gas filled tubes in all shapes and sizes.

Gas discharge lamps are used in virtually all areas of modern lighting technology including common fluorescent lighting for home and office - and LCD backlights for laptop computers, high intensity discharge lamps for very efficient area lighting, neon and other miniature indicator lamps, germicidal and tanning lamps, neon signs, photographic electronic flashes and strobes, arc lamps for industry and A/V projectors, and many more. Gas discharge automotive headlights are on the way - see the section: "HID automotive headlights".

Because of the unusual appearance of the light from gas discharge tubes, quacks and con artists also have used and are using this technology as part of expensive useless devices for everything from curing cancer to contacting the dead.

Unlike incandescent lamps, gas discharge lamps have no filament and do not produce light as a result of something solid getting hot (though heat may be a byproduct). Rather, the atoms or molecules of the gas inside a glass, quartz, or translucent ceramic tube, are ionized by an electric current through the gas or a radio frequency or microwave field in proximity to the tube. This results in the generation of light - usually either visible or ultraviolet (UV). The color depends on both the mixture of gasses or other materials inside the tube as well as the pressure and type and amount of the electric current or RF power. (At the present time, this document only deals with directly excited gas discharge lamps where an AC or DC electric current flows through the gas.)

Fluorescent lamps are a special class of gas discharge lamps where the electric current produces mostly invisible UV light which is turned into visible light by a special phosphor coating on the interior of the tube. See: Fluorescent Lamps, Ballasts, and Fixtures for more info.

The remainder of this document discusses two classes of gas discharge lamps: low pressure 'neon' tubes used in signs and displays and high intensity discharge lamps used for very efficient area and directional lighting.

Safely Working with Gas Discharge Lamps and Fixtures

Fixtures for gas discharge lamps may use up to 30,000 V while starting depending on technology. And, they are often not isolated from the power line. Neon signs are powered by transformers or electronic ballasts producing up to 15,000 V or more. Thus, the only safe way to work with these is to assume that they are potentially lethal and treat them with respect.

Hazards include:

- Electric shock. There is usually little need to probe a live fixture. Most problems can be identified by inspection or with an ohmmeter or continuity tester when unplugged.

  - Discharge lamps and fixtures using iron ballasts are basically pretty inert when unplugged. Even if there are small capacitors inside the ballast(s) or for RFI prevention, these are not likely to bite. However, you do have to remember to unplug them before touching anything!

    Neon signs using iron transformers are also inert when unpowered - just make sure they are off and unplugged before touching anything!

  - However, those using electronic ballasts can have some nasty charged capacitors so avoid going inside the ballast module and it won't hurt to check between its outputs with a voltmeter before touching anything. Troubleshooting the electronic ballast module is similar to that of a switchmode power supply. See the document: Notes on the Troubleshooting and Repair of Small Switchmode Power Supplies

  - The pulse starters of some high intensity discharge lamps may produce up to 30 kV during the starting process. Obviously, contact with this voltage should be avoided keeping in mind that 30 kV can jump over an inch to anyplace it wants!

- Nasty chemicals: Various toxic substances may be present inside high pressure discharge lamps (sodium and mercury) and neon signs (some phosphors). Contact with these substances should be avoided. If a lamp breaks, clean up the mess and dispose of it properly and promptly. Of course, don't go out of your way to get cut on the broken glass! WARNING: Metallic sodium reacts with water to produce hydrogen gas, an explosive. However, it is unlikely that the inner tube of a sodium vapor lamp would break by accident.

- Ultra-Violet (UV) light: High intensity discharge lamps generate substantial UV internally, often the particularly nasty UV-B variety. Unless designed to generate UV (for medicinal purposes, photoengraving, or whatever), the short wave radiation will be blocked by the outer glass envelope and/or phosphor coating. However, should the outer envelope break or be removed, the lamp will still operate (at least for a while - some have a means of disabling themselves after a few hours or less of exposure to air). DO NOT operate such a lamp preferably at all but if you do, at least take appropriate precautions to avoid any exposure to the UV radiation.

And take care around sharp sheet metal!

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Neon Technology

Neon Lights and Signs

Neon technology has been around for many years providing the distinctive bright glowing signs of commerce of all kinds before the use of colored plastics became commonplace.

Neon tubes have electrodes sealed in at each end. For use in signs, they are formed using the glass blower's skill in the shape of letters, words, or graphics. Black paint is used to block off areas to be dark. They are evacuated, backfilled, heated (bombarded - usually by a discharge through the tube at a very high current) to drive off any impurities, evacuated and then backfilled with a variety of low pressure gasses.

Neon is the most widely known with its characteristic red-orange glow. Neon may be combined with an internal phosphor coating (like a fluorescent tube) to utilize neon's weak short-wave UV emissions. A green-emitting phosphor combines with neon's red-orange glow to make a less-red shade of orange. A blue-emitting phosphor may be used to result in a hot-pink color. Neon may be used in tubing made of red glass to produce a deep red color.

Other colors are usually produced by tubing containing argon and mercury vapor. The mercury is the active ingredient, the argon produces negligible radiation of any kind but is important for the "neon" tubing to work. Clear tubing with mercury/argon glows a characteristic light blue color.

Such tubing is often phosphor-coated on the inside, to utilize the major short-wave UV emission of low-pressure mercury. In this way, much of the "neon" tubes in use are a kind of fluorescent lamp.

Phosphor-coated tubing with mercury can glow blue, blue-green, slightly white-ish green, light yellow, bright pink, light purple, or white.

Use of mercury vapor with colored tubing (with or without phosphors) can provide a lime-green or deep blue or deep violet-blue.

Nowadays, nearly all "neon" tubing contains neon or mercury vapor (with argon), whether with or without phosphors and/or colored glass. Well in the past, various colors were obtained (generally at reduced efficiency) by using different gases.

For example, helium can produce a white-ish orange light in shorter length, smaller diameter tubing. Hydrogen in this case makes a lavender-hot-pink color. These gases glow more dimly with duller color shades in larger tubing. Krypton makes a dull greenish color. Argon makes a dimmish purple color. Nitrogen (generally in shorter length tubing) makes a grayish purple-pink color. Xenon, which is expensive, generally glows with a dim bluish gray color, along with the glass tubing giving a slight dim blue fluorescence from very short wave UV from the xenon discharge. Krypton also often causes a dim blue glass fluorescence.

For general information on neon signs and technology including a neon FAQ, see:

- The Internet's Neon Shop

Power Supplies for Neon

Extremely high voltage power supplies are used to power neon signs. In the past, this was most often provided by a special current limited HV line transformer called a neon sign or luminous tube transformer. The output is typically 6,000 to 15,000 VAC at 15 to 60 mA. One such unit can power 10s of feet of tubing. This transformer acts as its own ballast providing the high voltage needed for starting and limiting the running current as well. Warning: the output of these transformers can be lethal since even the limited current availability is relatively high.

As with everything else, the newest neon sign power supplies use an electronic AC-AC inverter greatly reducing the size and weight (and presumably cost as well) of these power supplies by eliminating the large heavy iron transformer.

Small neon lamps inside high-tech phones and such also use solid state inverters to provide the more modest voltage required for these devices.

Neon Sign Installation

(From: Clive Mitchell (clive@emanator.co.uk)).

The voltage required to light a run of neon tube is variable according to diameter, gas type, pressure and number of tubes in circuit.

For a 15 kV transformer and neon gas you could run:

- 33 feet of 10 mm tube,
- 45 feet of 12 mm tube,
- 60 feet of 15 mm tube,
- 78 feet of 20 mm tube,
- 102 feet of 25 mm tube.

- Deduct one foot of tube for every pair of electrodes (tube section).

These figures are based on a chart in "Neon Techniques And Handling" which is the traditional neon reference.

The larger the diameter of the tube, the lower the voltage required, and the dimmer it will be. Transformers come with different current ratings. For larger diameter tubes, you can increase brightness by using a higher current.

- Don't attempt to run too much tube on a transformer, since it can cause breakdown of the insulation and destroy the transformer.

- Don't attempt to run too little tube on a transformer, since it can cause overheating and burn-out.

It is absolutely imperative that proper neon sign cabling and insulators are used, and that all local regulations are strictly followed. If you are intending to work with neon tubing, you should learn as much as possible first, since neon poses both a shock and serious fire risk if installed incorrectly.

The lengths quoted above may vary according to the transformer you use. The transformer manufacturers usually provide their own loading charts on request.

Anyone using this information does so at their own risk, and I cannot be held responsible for any horrible smouldering deaths experienced by incompetent dabblers, etc.

(From: Kenny Greenberg (kenny@neonshop.com)).

The neon circuit is not so simple. In a standard AC circuit neon acts like a diac - high breakover voltage followed by fast drop in resistance. Neon sign transformers are designed to 'leak' and thus self-regulate. You have a combined resistive and reactive circuit.

But take heart, it's all been figured out. :-)

There are a few variables:

1. A 'purely' neon filled tube (generally in the red range) has a higher voltage requirement than an argon-mercury tube (whose discharge is usually providing UV for phosphor with a wide range of colors.
2. The voltage requirement varies inversely with the tubing diameter. That is large diameters of a lower voltage requirement than small diameters.
3. The voltage requirement varies directly with tubing length.
4. The number of units (or pairs of electrodes) increases the voltage requirement because the electrodes have a voltage drop.
5. Wiring methods and length will also contribute to the formula but that's a whole 'nuther discussion.

You can download a free Neon Voltage Calculator for Windows.

An old tech method for determining the voltage requirement is to use a Variac on a large neon transformer. Bring the voltage down to where the neon just flickers. This should be at a point approximately 78% of the required voltage.

A better way involves using a milliameter to measure open circuit and closed circuit current and an rms voltmeter to measure actual operating voltage.

Problems With Neon

These fall into two categories:

1. Power supply - like fluorescent ballasts, the high voltage transformers can fail resulting in reduced (and inadequate) voltage or no power at all. Since they are already current limited, overheating may not result and any fuse or circuit breaker may be unaffected. The use of a proper (for safety if nothing else) high voltage meter can easily identify a bad transformer. If a high voltage probe is not available, position (with power off!) the ends of well insulated wires connected to the outputs of the transformer a fraction of an inch apart (about 1/32" per 1,000 V of transformer rating) and apply the power from a safe distance. If a hot arc results, the transformer is likely good (at least when cold).

2. Neon tubes - these may lose their ability to sustain a stable discharge over time as a result of contamination, gas leakage, or electrode damage (either from normal wear or due to excessive current). Check for obvious damage such as a cracked tube or cracked seals around the electrodes or badly deteriorated electrodes. A previously working tube that now will not strike or maintain a stable discharge on a known good transformer will need to be replaced or rebuilt.

Comments on Little Neon Bulbs and Tubes

The comments below relate to the little neon bulbs used as indicators, for voltage regulation or limiting, and other applications in all sorts of electronic equipment.

(From: Mark Kinsler (kinsler@frognet.net).)

Neon lamps can be used for voltage limiters and oscillator elements and just about anywhere else that a non-linear element is needed. The tremolo circuit in the classic Fender guitar amplifier uses a neon lamp relaxation oscillator. The neon lamp is heat-shrinked to a CdS photocell in the volume control circuit.

Less well-known is the fact that you can make a pretty reasonable computer logic element out of them: I believe that this was tried sometime in the 1940's.

Another cool use is as a radiation sensor: you bias the lamp so that it almost turns on, after which any incident radiation: radio waves (as in police radar), light, or gamma radiation will kick the lamp on. There were various circuits in the 1950's that used neon lamps to detect uranium, fight nuclear destruction, or escape the newly-developed police radar guns.

And finally, there's the mystery elevator button. Again, you bias the lamp so that it almost, but not quite, turns on. If you enclose the lamp properly, it'll stay off until you touch it. The electric field variation from your touch will turn the thing on, and it'll stay on. Such lamps are used in some self-service elevators: once the lamp is fired, the low voltage across it is sensed by the ancient logic circuits of the elevator controller and it'll send the elevator to the appropriate floor. These were a lot of fun in the 1960's. I think the controllers used vacuum tubes.

The problem with neon lamps is that they're not so reliable. Their turn-on voltage isn't particularly stable. This means that oscillators have a tendency to drift as the lamps age or when ambient radiation changes. I suspect that the computers are slow and cranky, and the radiation detector isn't anything you'd wish to stake your life or drivers' license on.

Still, they're great fun, and I have a fine time with them. One other use: hang a neon lamp across a telephone line to detect the ring signal. Place it in series with a piezo beeper, and you've got a reliable telephone ringer.

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High Intensity discharge Lamps

High Intensity Discharge (HID) Lamp Technology

These have been used for a long time in street, stadium, and factory lighting. More recently, smaller sizes have become available for home yard and crime prevention applications. Like other gas discharge lamps, these types require a special fixture and ballast for each type and wattage. Unlike fluorescents, however, they also require a warmup period.

There are three popular types:

- High pressure mercury vapor lamps contain an internal arc tube made of quartz enclosed in an outer glass envelope. A small amount of metallic (liquid) mercury is sealed in an argon gas fill inside the quartz tube. After the warmup period, the arc emits both visible and invisible (UV) light. High pressure mercury vapor lamps (without color correction) produce a blue-white light directly from their discharge arc. Phosphors similar to those used for fluorescent lamps can be used to give these a color closer to natural light. (Without this color correction, people tend to look like cadavers). Mercury vapor lamps have the longest life of this class of bulbs - 10,000 to 24,000 hours. The technology was first introduced in 1934 and was the first of the commercially viable HID lamps.

- Metal halide lamps are constructed along similar lines to mercury vapor lamps. However, in addition to the mercury and argon, various metal halides are included in the gas fill. The most popular combination is sodium iodide and scandium iodide. A few versions of this lamp have lithium iodide as well. A much less common version has sodium iodide, thallium iodide, and indium iodide. The use of these compounds increases the luminous efficiency and results in a more pleasing color balance than the raw arc of the mercury vapor lamp. Thus, no phosphor is needed to produce a color approaching that of a cool white fluorescent lamp with more green and yellow than a mercury vapor lamp (without correction). Some metal halide lamps have a phosphor that adds some orange-ish red light, but not much, since the metal halide arc does not emit much UV.

- High pressure sodium vapor lamps contain an internal arc tube made of a translucent ceramic material (a form of aluminum oxide known as "polycrystalline alumina"). Glass and quartz cannot be used since they cannot maintain structural strength at the high temperatures (up to 1300 degrees C) encountered here, and hot sodium chemically attacks quartz and glass. Like other HID lamps, the arc tube is enclosed in an outer glass envelope. A small amount of metallic (solid) sodium in addition to mercury is sealed in a xenon gas fill inside the ceramic arc tube. Some versions of this lamp use a neon-argon mixture instead of xenon. Basic operation is otherwise similar to mercury or metal halide lamps. High pressure sodium vapor lamps produce an orange-white light and have a luminous efficiency much higher than mercury or metal halide lamps.

  Since hot liquid sodium often eventually leaches through things and can get lost this way, sodium lamps have a surplus of sodium in them. Proper lamp operation depends on the sodium reservoir being within a proper temperature range.

Mercury vapor lamps are roughly as efficient as fluorescent lamps. Metal halide lamps are much more efficient, generally around 50 to 75 percent more efficient than fluorescent lamps. High pressure sodium lamps are roughly twice as efficient as fluorescent lamps.

Unlike fluorescent lamps, HID lamps will give full light output over a wide range of temperatures. This often makes HID lamps more suitable than fluorescent lamps for outdoor use.

When cold, the metallic mercury or sodium in the arc tube is in its normal state (liquid or solid) at room temperature. During the starting process, a low pressure discharge is established in the gases. This produces very little light but heats the metal contained inside the arc tube and gradually vaporizes it. As this happens, the pressure increases and light starts being produced by the discharge through the high pressure metal vapor. A quite noticeable transition period occurs when the light output increases dramatically over a period of a minute or more. The entire warmup process may require up to 10 minutes, but typically takes 3 to 5 minutes. A hot lamp cannot be restarted until it has cooled since the voltage needed to restrike the arc is too high for the normal AC line/ballast combination to provide.

Problems With High Intensity Discharge Lamps

While HID lamps have a very long life compared to incandescents (up to 24,000 hours), they do fail. The ballasts can also go bad. In addition, their light output falls off gradually as they age. For some types, light output may drop to half its original value towards the end of their life.

A lamp which is cycling - starting, warming up, then turning itself off - is probably overheating due to a bad bulb or ballast. A thermal protector is probably shutting down the fixture to protect it or the arc is being extinguished on its own. However, make sure that it is not something trivial like a photoelectric switch that is seeing the light from the lamp reflected from a white wall or fence and turning the fixture off once the (reflected) light intensity becomes great enough!

Sodium lamps sometimes "cycle" when they have aged greatly. The arc tube's discolorations absorb light from the arc, causing the arc tube to overheat, the sodium vapor pressure becomes excessive, and the arc cannot be maintained. If a sodium lamp "cycles", the first suspect is an aging bulb which should be replaced. Sodium lamp "cycling" used to be very common, but in recent years the lamp manufacturers have been making sodium lamps that are less prone to cycling.

If you have more than one fixture which uses **identical** bulbs, swapping the bulbs should be the first test. If the problem remains with the fixture, then its ballast or other circuitry is probably bad. Don't be tempted to swap bulbs between non-identical fixtures even if they fit unless the bulb types are the same.

Warning: do not operate an HID lamp if the outer glass envelope is cracked or broken. First, this is dangerous because the extremely hot arc tube can quite literally explode with unfortunate consequences. In addition, the mercury arc produces substantial amounts of short wave UV which is extremely hazardous to anything living. The outer glass normally blocks most of this from escaping. Some lamps are actually designed with fusable links that will open after some specified number of hours should air enter the outer envelope. Thus, an undetected breakage will result in the lamp dying on its own relatively quickly.

Troubleshooting a Discharge Lamp Fixture

(From: Greg Anderson (a3a30878@bc.sympatico.ca).)

The following applies directly to high pressure sodium lamps. It may also also be used for metal halide and mercury vapour lamp problems as long as references to the starter are ignored. (Metal halide and mercury vapour lamps do not have starters, except for "instant re-light" metal hhalide lamps.)

The starter produces about 2 to 5 kV spikes to ionize the gas in the lamp. The starter normally has a triac across the ballast and a diac trigger cct. When open cct voltage is across the lamp, the diac fires the triac to short the ballast, the triac then opens. This "kick" produces the voltage spike. Once the gas ionizes, the lamp impedance drops then gradually increases as the lamp warms up. The lamp running voltage is about 1/2 of the open cct voltage

With the lamp removed and power on, you can normally hear a good starter "ticking".

The open cct voltage is stamped on the ballast and is between about 150 and 350 Vac, depending on lamp wattage and ballast. Also, a capacitor is often connected in series with lamp to improve peaking and ballast action.

Steps to follow:

1. Bypass the photo cell - It may be bad
2. Check connections - water, salt, and bird poop are not good for wiring
3. Check the capacitor, if installed - normally they blow-up when bad
4. Check for open/shorted ballast.
5. Power up and check for starter "ticking"
6. REMOVE starter from cct and measure open cct volts
7. Check/Replace lamp
8. Check/replace lamp socket
9. Replace starter
10. Replace complete fixture.
11. Replace electrician. :)

Repairing a starter is not economically viable and often proves that electronic devices contain smoke and sometimes fire.

Ballasts and Bulbs Should be Matched!

HID bulbs generally need specific ballasts, and any given ballast can usually safely and effectively operate only one type or a few types of HID bulbs.

The bulb wattage must be matched to the ballast. A smaller bulb will usually be fed a wattage close to what the proper bulb takes, and will generally overheat and may catastrophically fail. Any catastrophic failures may not necessarily happen quickly. A larger bulb will be underpowered, and will operate at reduced efficiency and may have a shortened lifetime. The ballast may also overheat from prolonged operation with an oversized bulb that fails to warm up.

See The Discharge Lamp Mechanics Document (rather technical) for why it can be bad to underpower an arc discharge lamp.

Even if the ballast and bulb wattages match, substitutions can be limited by various factors including but not limited to different operating voltages for different bulbs. Examples are:

1. Pulse-start sodium lamps often have a slightly lower operating voltage than metal halide and mercury lamps of the same wattage, and ballasts for these sodium bulbs provide slightly more current than mercury and metal halide ballasts for the same wattage would. The higher current provided by the pulse-start sodium ballast can overheat mercury and metal halide lamps. Mercury and metal halide lamps may also "cycle" on and off in lower voltage sodium ballasts, such as many 50 to 100 watt ones.

2. Metal halide lamps have an operating voltage close to that of mercury lamps in many wattages, but have stricter tolerances for wattage and current waveform. Metal halides also usually need a higher starting voltage. Most metal halide lamps 100 watts or smaller require a high voltage starting pulse around or even over 1,000 volts.

175 to 400 watt metal halide lamp ballasts can power mercury lamps of the same wattage, but the reverse is not recommended. Mercury lamps 50 to 100 watts will work on metal halide ballasts, but hot restriking of mercury lamps 100 watts or smaller on metal halide lamps may be hard on the mercury lamp since the starting pulse can force current through cold electrodes and the starting resistor inside the mercury lamp.

3. 1,000 watt mercury lamps come in two operating voltages, one of which is OK for 1,000 watt metal halide ballasts. A few wattages of pulse-start sodium (150 watts?) come in two voltages.

   A low voltage lamp in a high voltage ballast will be underpowered, resulting in reduced efficiency, possible reduced lamp life, and possible ballast overheating. A high voltage lamp in a low voltage ballast will usually cycle on and off, operate erratically, or possibly overheat. This will usually result in greatly reduced lamp life in any case.

4. One class of sodium lamps is made to work in mercury fixtures, but these only work properly with some mercury ballasts, namely:

   - 'Reactor' (plain inductor) ballasts on 230 to 277 volt lines.

   - 'High leakage reactance autotransformer' ballasts, preferably with an open circuit voltage around 230 to 277 volts. NOT 'lead', 'lead-peak' nor any metal halide ballast!

   These sodium lamps may suffer poor power regulation and accelerated aging in the wrong mercury ballasts, especially after some normal aging changes their electrical characteristics. Also, these lamps may overheat and will probably have shortened life with pulse-start sodium ballasts.

5. Many sodium lamps require a high voltage starting pulse provided only by ballasts made to power such lamps.

Operation of Discharge Lamps on DC

Sometimes, one may want to run a discharge lamp on DC. There are two possible reasons:

- Only DC power is available.

- To reduce flicker. Sometimes, the lamp performs differently for electricity flowing in one direction than the other. In addition, the positive and negative ends of the arc can make different amounts of light, resulting in a flicker rate equal to the AC frequency rather than twice the AC frequency.

  However, end flicker is usually not significant. In HID lamps, the total arc size is generally small. Only if the fixture has a reflector that causes some areas to receive light from only one end of the arc should end flicker be significant. In most multi-tube fluorescent fixtures, the tubes are usually in series pairs with the two tubes in any pair oriented in opposite directions. This generally reduces end flicker effects, especially in fixtures with diffusing lenses.

  Bulbs should perform close enough to identically in both directions, unless the bulb is near the end of its life. In such a case, one electrode deteriorates enough to affect performance before the other does. However, this generally indicates a need to replace the bulb rather than to attempt to make it flicker less.

If you want to rectify the AC to provide the bulb with DC, use a bridge rectifier after the ballast. Most ballasts, including all "iron" types, require AC of the proper voltage and frequency to work. Do this only if only two wires feed the bulb. Otherwise, diodes in the bridge rectifier may short parts of the ballast to each other, at least for half the AC cycle. Problems can also occur with fluorescent ballasts with filament windings. Only fully isolated filament windings or separate filament transformers should be used if you rectify the output of a ballast with filament windings. Also, the bridge rectifier must withstand the peak voltage provided by the ballast.

If the power supply is DC of adequate voltage, you need a resistor ballast or an electronic ballast specifically designed to run your lamp from the available DC voltage. "Iron" ballasts only limit current when used with AC. Preheat fluorescent lamps operated from DC supplies and without special ballasts need both the usual "iron" ballast to provide the starting "kick" and a resistor to limit current.

In addition, most discharge lamps are only partially compatible with DC, and some are not compatible at all.

Mercury vapor and fluorescent lamps generally work on DC. However, the life may be shortened somewhat by uneven electrode wear.

Fluorescent lamps may get dim at one end with DC. Since the mercury vapor ionizes more easily than the argon, some of it exists as positive ions. This can cause the mercury to be pulled to the negative end of the tube, resulting in a mercury shortage at the positive end. This is more of a problem with longer length and smaller diameter tubes.

Some fluorescent fixtures made for use where the power available is DC have special switches to reverse polarity every time the fixture is started. This balances electrode wear and reduces mercury distribution problems.

Mercury vapor lamps generally work OK with DC, but some may only reliably work properly if the tip of the base is negative and the shell of the base is positive. This is because the starting electrode does its job best when it is positive.

In addition, if the nearby main electrode is positive, it may cause a thin film of metal condensation that shorts the starting electrode to the nearby main electrode. This may make some brands, models, and sizes of mercury lamps unable to start after some use. The negative main electrode will not release as much vaporized electrode material, since the electrode material easily forms positive ions making the electrode material vapor tend to condense on the electrode rather than condense on nearby parts of the arc tube.

Metal halide and sodium lamps should not get DC. Use these only with ballasts that give the bulb AC. In metal halide lamps, ions from the molten halide salts can leach into hot quartz in the presence of a DC electric field. This can cause strains in the quartz arc tube. At the ends of the arc tube, electrolysis may occur, releasing chemically reactive halide salt components that can damage the arc tube or the electrodes. The arc tube may crack as a result.

There are a few specialized metal halide lamps that are made to work on DC. These often have asymmetrical electrodes and/or short arc lengths. These lamps often also must be operated only in specific positions, and only with the type of current they were designed for in order to achieve the proper distribution of active ingredients within the arc tube and to achieve proper electrode usage. For example, some of these lamps may go wrong in some way or another with AC.

In high pressure sodium lamps, which contain both sodium and mercury, the sodium forms positive ions more easily than the mercury does and drifts towards the negative electrode. The positive end can go dim from a lack of sodium. In addition, if any part of the arc tube is filled with a mixture containing excessive sodium and a lack of mercury, heat conduction from that part of the arc to the arc tube will increase. Furthermore, the hot arc tube may suffer electrolysis problems over time in the presence of sodium ions and a DC electric field.

Low pressure sodium lamps should not get DC for the same reasons. The sodium is likely to drift to the negative end of the arc tube, and hot glass will almost certainly experience destructive electrolysis problems if exposed to hot sodium or sodium ions and a DC electric field.

Special purpose HID lamps such as xenon and HMI

The usual general purpose HID lamps are mercury vapor, metal halide, and high pressure sodium. You can get these at home centers, although usually only in wattages up to 400 watts. These versions of HID lamps are optimized for high efficiency, long life, and minimized manufacturing cost.

However, the arc surface brightness of these lamps is roughly equal to the surface brightness of incandescent lamp filaments and general purpose halogen lamp filaments. For some applications such as endoscopy and movie projection, it is necessary to have a much more concentrated light source. This is where specialized HID lamps such as short arc lamps and HMI lamps come in.

Short arc lamps consist of a roughly spherical quartz bulb with two heavy duty electrodes spaced only a few millimeters apart at the tips. The bulb may contain xenon or mercury or both. Mercury short arc lamps have an argon gas fill for the arc to start in.

In a short arc lamp, the arc is small and extremely intense. The power input is at least several hundred and more typically a few thousand watts per centimeter of arc length. The operating pressure in the bulb is extremely high - sometimes as low as 20 atmospheres, more typically 50 to over 100 atmospheres. These lamps are an explosion hazard!

Mercury short arc lamps are used when a compact, intense source of UV is needed or where one cannot have the high voltage starting pulses needed for xenon short arc lamps. Mercury short arc lamps are slightly more efficient than xenon ones. The pressure in a mercury short arc lamp does not need to be as high for good efficiency as in a xenon one, but is still tremendous.

Xenon short arc lamps are more common than mercury ones, since they do not require time to warm up the way mercury lamps do and have a daylight-like spectrum. A disadvantage of xenon is the requirement of a very high voltage starting pulse - sometimes around 30 kilovolts!

Xenon short arc lamps are used for movie projection and sometimes for searchlights. Lower wattage ones are used in specialized devices such as endoscopes.

HMI lamps are metal halide lamps with a more compact and more intense arc. The arc is larger and less intense than that of a short arc lamp. Typical power input is hundreds of watts per centimeter of arc length, but gets to a few kilowatts per centimeter in the largest ones.

HMI lamps are used in some spotlights. They are used in some endoscopes and projection applications where the intensity of the HMI arc is adequate since they cost less and last longer and are more efficient than true short arc lamps.

There are all sorts of HMI and similar lamps, including HTI lamps and the lamps used in HID auto headlights.

HID Automotive Headlights

First there were gas lamps, then there were electric bulbs, then sealed beam, then halogen. Now, get ready for - drum roll please! - high intensity discharge lamps with sophisticated controllers. High-end automobiles from makers like BMW, Porsche, Audi, Lexus, and now Lincoln are coming equipped with novel headlight technology. No doubt, such technology will gradually find its way into mainstream automobiles - as well as other applications for mortals.

Among the potential advantages of HID headlights are higher intensity, longer life, superior color, and better directivity:

- Light intensity - HID lamps are about 3 times as efficient as halogen lamps. Thus, even when the efficiency of the DC-DC converter is taken into consideration, the lower power input can actually result in much brighter headlights than are possible with halogen bulbs. This reduced power also leads to cooler operation and less drain on the battery and alternator.

- Lifespan - an HID lamp can be expected to last 2,700 hours or more and thus covered under the bumper to bumper warranty for 100,000 miles. As a practical matter, the HID lamp may outlast the automobile. Since warranty replacement of headlights turns out to be a significant expense, there is strong incentive to see this long lived technology take off.

- Spectral output - the light from the HID lamp is richer in blue (and more like daylight) than halogen bulbs. This turns out to enhance reflectivity of signs and road markings.

- Beam pattern - the small arc size of the HID lamp permits the optical system to be optimized to direct light more effectively to where it is needed and prevent it from spilling over to where it is not wanted.

In order to make this practical - even for a $40,000 Lexus - special DC-DC converter chips have been designed specifically with automotive applications in mind. These, along with a handful of other basic electronic components, implement a complete HID headlight control system.

The HID bulb itself is similar in basic design to traditional HID lamps: Two electrodes are sealed in a quartz envelope along with a mix of solids, liquids, and gasses. When cold, these materials are in their native state (at room temperature) but are mostly gases when the lamp is hot. Starting of these lamps may require up to 20 KV to strike an arc but only 50 to 150 V to maintain it. Lamps may be designed to operate on either AC or DC current depending on various factors including the size and shape of the electrodes. A unique set of ballast operating parameters must be matched to each model HID bulb.

Of all the problems that had to be addressed for HID headlights to become practical (aside from the cost), the most significant was the warmup time. As noted in the section: "High intensity discharge (HID) lamp technology", common HID lamps require a warmup period of a few minutes before substantially full light output is produced. This is, of course, totally unacceptable for an automotive headlight both for cold start (imagine: "Honey, I have to go cook the headlights") as well as when they need to be blinked. The warmup problem was solved by programming the controller to deliver constant power to the lamp rather than the more common nearly constant current that would be provided by a traditional ballast. With this twist along with a special lamp design, the lamp comes up to at least 75% of full intensity in under 2 seconds. The controller also provides 'hot strike' capability for blinking (recall that HID lamps typically cannot be restarted when hot). Thus, restarting a hot lamp is absolutely instantaneous.

While this technology is just beginning to appear, expect inroads (no pun intended) into household, office, store, factory, and other area and work lighting. The combination of high efficiency, long life, desirable spectral characteristics, small size, and solid state reliability should result in many more applications in the near future. The nearly instant starting capability addresses one of the major drawbacks of small HID lamps.

If you have some time and money to spare:

(From: Declan Hughes (hughes@aero.tamu.edu).)

Check out: OSRAM Sylvania Products Inc.

They have a "sample" for sale at $250.00 for one lamp including the 12 VDC electronic ballast. 42 W total power, 35 W light power, 3,200/2,800 lm output (there are two types, D2S and D2R), 2,000 hours rated lifetime, 91/80 lm/W luminous efficacy, 4,250/4,150 K color temperature, 6,500 cd/cm^2 average luminance, 4.2 mm arc length, burning position horizontal +/- 10 deg., luminous flux after 1 sec. = 25%, max. socket temp. = 180 deg C, any errors are mine.

For more info, look in Don Klipstein's Automotive HID Lamp File.

Substitution of Metal Halide Lamps?

The following was prompted by a request for info on replacing an (expensive) 250 watt metal halide lamp in a video projector with something else.

I would not substitute this lamp, for many reasons below:

The metal halide lamp requires a ballast. The ballast should only run a 250 watt metal halide lamp of the same arc voltage. You will have to measure the arc voltage yourself after the lamp warms up, and do this without exposing yourself to the nasty UV that some of these things emit but which does not pass through glass. Arc voltages of many specialized metal halide lamps are not widely published and may or may not be available from the lamp manufacturer.

WARNING: The strike voltage on these may be several kV which will probably obliterate your multimeter should the arc drop out and attempt to restart while you are measuring it! Either the operating or strike voltage may obliterate you should you come in contact with live terminals! (Special metal halides probably usually only need a couple to a few kV. Xenon metal halide automotive lamps need 6 to 12 kV to strike and 15 to 20 kV for hot restrike. The worst are short arc xenon that may use up to 30 kV or more.)

Most metal halide lamps are AC types and some are DC and you can only use AC lamps on AC output ballasts and DC lamps on DC output ballasts. Different metal halide lamps may have different requirements for starting voltage also.

If you match arc voltage, AC/DC type, and the ballast will start the lamp, you might be in business but good chance not. Many projector lamps have specific cooling requirements and some have specific burning position requirements. Metal halide lamps may prematurely fail (possibly violently!) if they overheat, in addition to being off-color. If overcooled, they are more like mercury lamps and will be off-color and have reduced light output. In addition, some metal halide lamps have a halogen cycle in them to keep the inner surface of the bulb clean, and that may not work if the lamp is overcooled and not enough of the chemicals in the bulb get vaporized. This could also even make the lamp fail.

If you get the alternate lamp to operate satisfactorily, the arc may be in a different location from that of the original lamp. The arc may be of a different shape or size than that of the original lamp. This can affect your projection. Your projection may not get much light or may have illumination of only part of the picture.

The arc may have a different color or spectrum, which can affect the color rendering of what's being projected. Metal halide arcs are often not of uniform color, and if the alternate lamp has a less color-uniform arc than the original lamp then your pictures may have strange color tints in them.

As for using a halogen instead of metal halide? You will get less light, as well as problems from the filament having a different shape or size than the original metal halide arc does. Most likely, the filament is larger or longer than the arc and this will reduce the percentage of the light being utilized. Should you try a halogen lamp hack, you will almost certainly have to bypass the metal halide ballast. And halogen lamps emit more infrared than metal halide lamps of the same wattage - you might overheat the source of your image (e.g., LCD panel or transparency).

I would not recommend substituting a projector lamp for all of these reasons. This should only be tried at your own risk and only by those that are very familiar with all of the characteristics of the lamps in question - including being familiar with burning position requirements, cooling requirements, shape and size of the light-emitting region, etc.

Projector lamps in general, and especially specialized HID lamps, should be used only in equipment made specifically to use the particular lamps in question, or by those who know about these things well enough to make their own ballasts and know the other messy things about these lamps. And you may not save much by using a different lamp - specialized metal halide lamps are all expensive.

And for anyone shopping for any sort of projector - look into price, availability, and life expectancy of lamps!

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Low Pressure Sodium Lamps

(Portions from: Bruce Potter (s60231@aix2.uottawa.ca))

Low pressure sodium lamps are the most efficient visible light sources in common use. These lamps have luminous efficacies as high as 180 lumens per watt.

A low pressure sodium lamp consists of a tube made of special sodium-resistant glass containing sodium and a neon-argon gas mixture. Since the tube is rather large and must reach a temperature around 300 degrees Celsius, the tube is bent into a tight U-shape and enclosed in an evacuated outer bulb in order to conserve heat. As an additional heat conservation measure, the inner surface of the outer bulb is coated with a material that reflects infrared but passes visible light. This material has traditionally been tin oxide or indium oxide.

The electrodes are coiled tungsten wire coated with thermionically emissive material, and somewhat resemble the electrodes of fluorescent lamps. Unlike most fluorescent lamps, low pressure sodium lamps have only one electrical connection to each electrode and the electrodes cannot be preheated.

The gas mixture is a "Penning" mixture, consisting mainly of neon with a small amount of argon. Depending on who you listen to, this mixture is .5 to 2 percent argon, 98 to 99.5 percent neon. More argon-rich mixtures around 98-2 may be favored today since hot glass has some ability to absorb argon from a low pressure electric discharge. Ideally the mixture should be only a few tenths of a percent argon, in order to ionize most easily and do so much more easily than pure neon or pure argon.

A significant surplus of sodium is contained in the glass arc tube since the glass may absorb or react with some of the sodium. The sodium vapor pressure is controlled by the temperature of the coolest parts of the arc tube. When the arc tube reaches a proper temperature, further heating is reduced by the lamp's efficiency at producing light instead of heat.

The arc tube has dimples in it, which are normally slightly cooler than the rest of the arc tube. This causes the sodium metal to collect in the dimples instead of covering a larger portion of the arc tube and blocking light.

The low pressure sodium lamp usually requires 5 to 10 minutes to warm up.

The light of low pressure sodium consists almost entirely of the orange-yellow 589.0 and 589.6 nM sodium lines. This light is basically monochromatic orange-yellow. This monochromatic light causes a dramatic lack of color rendition - everything comes out in an orange-yellow version of black-and-white! This can cause some confusion in parking lots since cars become more alike in color.

Some basically red and reddish color fluorescent inks, dyes, and paints can fluoresce red to red-orange from the yellow sodium light and these will stand out in sodium light with color differing from that of the sodium light.

Another disadvantage of low pressure sodium light is that many objects will look darker than they would with an equal amount of other light. Red, green, and blue objects look dark under low pressure sodium light. Most other sources of light of sodium-like color such as "bug bulbs" have significant red and green output and will render red and green objects at least somewhat normally.

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