How Luminous Lamps Work

What happens inside a Cold Cathode or Neon light.

Fundamentally, the luminous tube is a very simple device. It consists of an evacuated glass tube fitted at each end with a metal terminal called an electrode. Inside the tube is a small amount of highly purified inert gas. Connected to the two electrodes is a source of high-voltage electrical power. When the current is turned on, the tube glows with a steady, piercing light.

A practical person can learn how to bend the glass, attach the electrodes, pump out the air, fill the tube with neon or some other gas, seal it, mount it, connect it to the power source, and install the completed tube. All these things can be done without knowing how or why the tube works.

But what happens if the newly installed tube goes dead in two weeks, or if the fluorescent tubing starts darkening and visibility decreases? A great deal of future trouble can be saved by knowing some simple facts about what the glow discharge is and under what conditions it will deliver satisfactory service.

Sparks and glow discharges

The familiar glow of the neon sign is a first cousin of man's oldest electrical acquaintance, lightning. The red glow of neon and the blue flash of lightning are both electrical discharges in gas. In the neon sign, the gas is neon. In lightning, the gas is the air: a mixture of oxygen, nitrogen, carbon dioxide, traces of other, rare, gases, and water vapor. In the luminous tube, the pressure is very low, in fact, a partial vacuum. Lightning occurs in normal atmospheric pressure. But the neon glow and the lightning flash are electrically very much alike. They both illustrate the fact that when electricity passes through a gas, light is given off.

If lightning and neon glow are so much the same, what makes their light so different? The differences are due to the factors described above; that is, differences in pressure and in the kind of gas used. The lightning spark is hot and blue-white in color. It consumes and transforms a tremendous amount of energy. By using a particular gas at a reduced pressure in a glass tube, it is possible to produce a steady glow, with very little power and very little heat.

The combination of penetrating light, high economy and design flexibility makes the luminous tube a highly effective source of light for advertising, lighting, and decoration. The large industry based on luminous tubes, as outlined in the previous chapter, has resulted from the practical application of this low-pressure electrical gas discharge.

What happens inside the tube

The gas inside the tube consists of particles called molecules. Under ordinary conditions, these molecules are electrically neutral; that is, they are neither positively nor negatively charged. To start the gas discharge, these molecules must be broken up into electric charges. When this happens, a current can flow through the gas, and this current produces the desired light.

When a molecule loses or gains one or more electrons, it is no longer electrically neutral and assumes a positive or negative charge. This charged molecule is called an ion, and the process of gaining or losing electrons is called ionization. In any gas, there is always a very small percentage of molecules that are naturally ionized at any given time.

This natural ionization results from such sources as cosmic rays generated from the sun, and natural background radiation that exists on earth. Radiation dislodges electrons from the outer orbits of electrons surrounding the gas molecule's nucleus. If an electron is removed, the remainder of the molecule becomes positively charged, and the result is the division of this small percentage of the gas into positive ions and negative electrons.

Because like electrical charges repel one another and unlike charges attract each other, a free electron is strongly attracted to any nearby positive ion. This attraction leads to the rapid merging of the positive ions and negative electrons into one neutral molecule. During this process, the remaining electrons within the molecule rearrange themselves, which causes the molecule to give off light. This is the light we want to produce, and its color depends upon the kind of molecule (or gas).

Thus, to produce a gas discharge, electrons must be removed from neutral molecules and recombined with positive ions to form other neutral molecules. The practical way of producing this ionization is by passing a current through the gas.

How the current produces the glow

When voltage is applied to the electrodes, one electrode becomes, momentarily at least, positively charged, as shown in Figure 1. The electrode attracts any free negative electrons that may be present in the gas. If the voltage is high enough, the electrons will be attracted with tremendous force and will accelerate toward the positive electrode reaching speeds of thousands of miles per second.

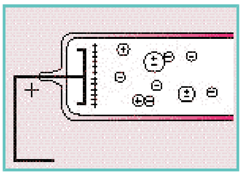

Figure 1: Action of electrons and positive ions in gas-filled tube.

Before one of these electrons can get very far, however, it collides with a neutral gas molecule that lies in its path. It hits this molecule with such force that one or more (usually more) electrons are liberated. These electrons, once free, start off toward the positive electrode. They soon collide with other neutral molecules, liberating still more electrons, which go off to smash still other molecules.

Shortly after voltage is applied to the tube, the whole body of gas is in motion. Electrons are liberated from molecules, free electrons combine with positive ions, giving off light as they do so, and then are blasted apart again.

The voltage supplied by the luminous tube power supply is alternating; that is, it reverses itself many times every second. In the US, current reverses itself 60 times per second for conventional electrical systems and newer electronic systems reverse up to 20,000 times (or more) per second.

Each electrode takes its turn being the positive one, and as a result, the glow is distributed evenly over the whole tube. If direct current had been used, with one electrode remaining positive, the situation shown in (a) and (b) of **Figure 2** would occur. This undesirable condition is avoided by the use of alternating current.

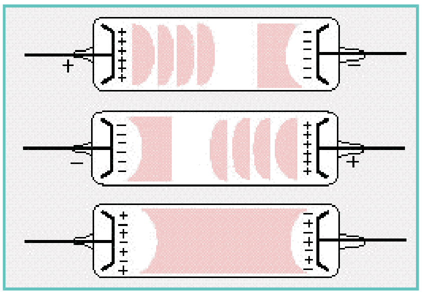

Figure 2 Schematic diagram of low pressure gas-filled tubes. The top two show the distribution of the positive column when direct current is used. When alternating current is used (bottom), the distribution is even.

The reason for high voltage

Unless high voltage is used, the electrons will not be attracted strongly enough to start the ionization process. Without ionization, no current will flow and no light will appear. Hence, a high voltage must be used. Transformers are built with secondary voltages that vary from 2000 to 15,000 volts for signs. In cold-cathode ballast systems, the secondary voltage is standardized at 750 or 900 volts.

Once the glow discharge has begun, however, less voltage is required to keep it operating. In fact, if the original, high starting voltage is maintained, the current becomes too great, and the gas heats up excessively. The tube will consume a great deal of power, become very inefficient, and its life will greatly decrease. Therefore, some means must be provided for lowering the voltage after the glow has started.

A special type of transformer, made especially for luminous tubes called a high-leakage reactance transformer, performs this voltage reduction automatically. The method used is described in detail in a later chapter.

Operating current

The electric current that passes through the luminous tube determines the tube's brightness. If the current is too low, the tube will lack brilliance; if it is too high, the tube will overheat and have a very short life. The required operating current depends upon the diameter of the tubing, the kind of electrodes used, the kind of gas and its pressure. Each of these factors must be correct so that the operating current is neither too small nor too large.

The current of neon signs and cold-cathode tubing is measured in milliamperes. A milliampere is one-thousandth of an ampere, which is the standard electrical unit of current. Operating currents in standard signs run from 15 to 60 milliamperes. In cold-cathode lighting operating currents may run up to 120 milliamperes.

The current through the tube is accompanied by the passage of free electrons from the gas into the electrodes. The higher the current, the more electrons will flow to the electrodes in a given time. Each time that an electron hits the electrode, the energy with which it hits is transformed into heat, and as a result, the electrode heats up. If the current is excessive, the electrode will begin to disintegrate, or even to melt. Hence, electrodes must be designed to withstand considerable heat, although even with proper design they cannot last if the operating current is too high.

The effect of gas pressure

We have already seen that a steady glow is possible only if the gas in the tube is at a reduced pressure. The pressure is the force with which the gas inside the tube presses against the glass wall of the tube. Pressure might be expressed as pounds per square inch (psi), as air pressure is often expressed. (Normal air pressure, or "atmospheric pressure" is approximately 14.7 pounds per square inch at sea level). Usually, however, pressures in luminous tubes are expressed in terms of the height of the column of mercurywhich that pressure will support.

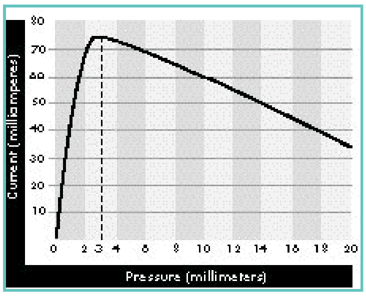

Figure 3: Curve showing increase of current as pressure is reduced (tube fed from constant-voltage source). Note decrease of current when pressure falls below 3 millimeters.

At sea level, air pressure will support a column of mercury to about 760 millimeters or 29.9 inches. The pressure of the atmosphere is thus referred to as a pressure of 760mm. When the tube is pumped out, the small amount of gas that still remains in the tube can exert only a small pressure, compared with that of the air-filled tube. The gas pressure in a luminous tube, for example, is usually between 3 and 20mm. The larger the diameter of tubing used the lower is the pressure required. Vacuum pressure measured in luminous tubes, before filling with gas, often goes down to less than 0.001mm.

The amount of current that will flow through the tube depends largely on the pressure. To realize why this is true we must remember that in a gas at low pressure, there are fewer atoms per cubic inch than in a gas at higher pressure. That is, in the low-pressure gas, the atoms are fewer in number and farther apart from one another. In the low-pressure gas, therefore, the free electron has a longer distance in which to get up speed before it hits a neutral atom. As a consequence, when the free electron hits, it hits much harder, and more free electrons are liberated than otherwise would be free, and the whole action is much more intense. Hence, as the pressure is lowered, the current will increase. This is the general rule for pressures encountered in luminous tubes.

If, however, the pressure is reduced so much that a nearly perfect vacuum forms inside the tube, then there are so few atoms available that the current will decrease from sheer lack of electrons and ions, even though the electron speeds are very high. Consequently, it is found that, after a certain point is reached in lowering the pressure, the current begins to decrease again. The effect of pressure on current is shown graphically in **Figure 3**.

The effect of diameter of the tubing

Glass tubes for sign-lighting purposes usually vary between 7 and 15mm in outside diameter. These sizes are convenient to work with in practical applications. In many countries outside the US, signs are made with larger tubing, up to 20mm in diameter. In general, tubes larger than 15mm in diameter are not used because the current available from standard sign transformers is limited to 60 milliamperes (mA). This amount of current can light a 15mm tube at standard pressure effectively. If the same current were applied to a larger tube, the light would spread thinly throughout the tube, nullifying its effectiveness as a light source.

In general, the smaller the tube used, the more brilliant the light. To obtain the maximum brilliance with the larger sizes of tubing, it is sometimes necessary to use slightly higher operating currents. The smaller the diameter of the tubing, the higher the resistance, and the higher voltage required to operate a foot of tubing. **Figure 4** shows the relationship between the necessary voltage and the diameter of the tube.

The foregoing remarks apply to luminous tubes of the nonfluorescent type of cold-cathode lighting. In fluorescent lighting, large-diameter tubes are often used, up to 25mm outside diameter in the cold-cathode types, and up to 54mm in the hot-cathode types.

One reason for the larger diameter of the fluorescent tubes is the fact that the light is very intense, and the surface brightness of the tube is reduced by spreading the light over the larger area. This is particularly important in white tubes used for interior lighting, because too high a surface brightness may prove annoying to the eyes in interior installations.

The gases used for luminous tubes

No attempt will be made to go into details here concerning the gases used in luminous tubes, because they are fully described in the following chapter. In this introduction, only their electrical characteristics will be discussed, in relation to other electrical properties of the tubes.

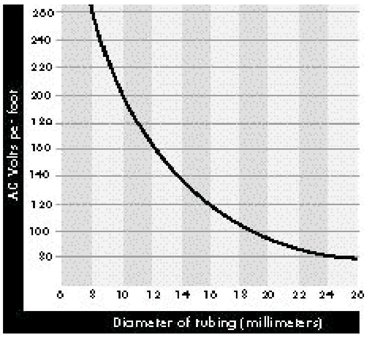

Figure 4: The voltage per foot required to operate tubing of various diameters filled with neon gas (no mercury)

The rare gases -- neon, argon, helium, xenon and krypton -- are ideally suited for use in signs. The voltage per foot needed to produce a suitably brilliant light is much less than more common gases, such as nitrogen and carbon dioxide. But the gases with the lowest resistance are not those that produce the most light.

Argon, for example, has a very low resistance, lower than that of neon, but its light is comparatively weak. To obtain the advantages of low resistance and good light emission, gases are sometimes combined. Low-resistance gases are mixed with the good light givers to produce a compromise having the advantages of each type of gas. Most often, mercury vapor and a low resistance gas are combined.

The use of mercury

The most efficient and only practical way of producing many colors requires mercury vapor and a carrier gas. Vapor differs from gas in that a vapor can exist only as it evaporates from a liquid, while a gas can exist of its own accord.

To obtain mercury vapor, therefore, it is necessary to insert liquid mercury in the tube. As will be shown in later chapters the light from mercury vapor isn't only useful for its visible component but also for its invisible ultraviolet component. The ultraviolet portion of the light can be used to energize chemicals known as phosphors, which when excited radiate a whole spectrum of colors, producing the majority of the wide array of colors used in signage today.

To start a current flowing through mercury vapor is not as easy as with a gas, and for this reason a gas (usually argon or argon-neon mixture) is mixed with the vapor to aid the current flow. This extra gas also contributes somewhat to the light of the discharge, but its main function is that of a current carrier. The mercury vapor, like other vapors, is very much affected by changes in temperature; it will condense as the temperature is lowered. Thus, the light will become much more intense after the sign has had a chance to warm up.

In extremely cold weather, the sign may never come up to full brilliance unless it is properly constructed. In installations subject to extreme cold, special starting gases containing helium or neon are often used. The heat of these gases or mixtures maintains the mercury-vapor pressure. All these factors must be taken into account in designing a sign for the particular job that is required. In general, the smaller the diameter of tubing used, the higher the resistance per foot and the hotter the tube will get, allowing the mercury to vaporize more readily. In cold weather, however, small-diameter mercury tubes are often found to fade out while larger tubes remain bright. This is due to the higher heat losses of smaller-diameter tubes.

Chemical effects inside the tube

The action of the luminous tube in producing light of the required brilliance and color depends wholly upon the electrical ionization of the gas within it. If the action could be restricted to a purely electrical one, there would not be concerns as to the sign continuing to function properly. Unfortunately, there are many possible chemical actions which may start within the tube if special precautions are not taken. These chemical actions almost universally lower the efficiency of the tube. If any impurities, such as dirt, grease, or impure gas, are left in the tube after it is sealed off, these impurities, under the action of heat and electrical stress, become chemically active. As they combine with one another, they may blacken the glass, they may combine with the metal of the electrodes, or, if the heat is intense, they may liberate gas inside the tube. If this last possibility occurs, the unwanted gas will become ionized, and it will give off light and usually excess heat which leads to further release of impurities resulting in a tube that progressively gets worse until failure. This accounts for the fact that neon tubes often turn blue when they go bad. Many failures in tube making result from insufficient care in eliminating the impurities during pumping and filling. The gas inside the tube must be pure and the glass and electrodes must be thoroughly clean if undesirable chemical effects are to be avoided. Above all, the mercury must be the purest obtainable.

Bombarding, an essential operation in tube making

Removing the chemical impurities is not so easy a task as may be supposed. Although the electrodes, the glass, and the rare gas may appear to be clean, they actually harbor many impurities that cling to the surface or are in the glass structure itself and which cannot be removed by merely pumping them out. The best way of getting rid of them is to heat the tube before or during the time it is being pumped out. The heat drives the gas and other impurities from both the metal and glass in the form of gas or vapor. The vacuum pump removes these gases, and if the heating process is kept up long enough, the vast majority of all of them are removed. The tube may then be filled with rare gas and sealed off.

The simplest way of heating the tube and electrodes is by passing a current through the tube while it is still on the pump. This can only be done when the air pressure has been reduced sufficiently to allow a heavy current to flow. This heavy current, usually much higher than the operating current, will pass through the low-pressure air in the tube, giving off much light and heat in the process. The light serves no purpose except to show that the bombardment, as it is called, is actually taking place. The heating has the desired effect of ridding the tube of its impurities. Bombardment is a most important and exacting process. A later chapter has been devoted, therefore, to explaining what it is and how it should be carried out.

Electrodes, tube life and sputtering

The electrode has the task of carrying current from the power supply wires to the rare gas. Because it is continually subjected to the bombarding of electrons and ions, it heats up, and therefore must be designed to withstand heat. Since the metal is hot, it is highly active chemically, and may combine with gases or impurities within the tube. But by far the greatest difficulty with electrodes arises from what is known as "sputtering." Sputtering occurs when the electrode, under the impact of the heavy ions, flies to pieces bit by bit. The metal of the electrode gradually flies off and coats the inside of the glass tube. This effect in itself causes no harm, since the blackening caused by the metal deposit is confined to the ends of the tubes near the electrodes. Eventually, of course, the entire electrode is consumed by the process, but since the action is very slow, the electrode will nevertheless last for normal life. However, sputtering is accompanied by a decrease of gas pressure in the tube. This loss of pressure eventually makes the tube inoperative.

The sputtered metal from the electrode absorbs some of the fill gas in the tube. As the gas is absorbed, the pressure in the tube is reduced leading to what is called "hardening" of the tube. The reduced gas pressure means there are fewer gas molecules in the tube and the electrons and ions can travel greater distances before hitting each other or a gas molecule. These particles therefore can build up significant speed before they impact the electrode. The high energy impact on the electrode causes a good deal of heat in the glass near the electrode. Eventually the glass around the electrode will heat until the relative vacuum in the tube sucks in the hot glass, causing the tube to fail. In the early days, this sort of trouble was very common; in fact, the short life of tubes (due to sputtering) was one of the greatest hindrances to the commercial introduction of tube lighting.

Sputter control

The logical solution to the sputter problem is to build electrodes that will not sputter under ordinary conditions. Some sputtering will always occur, and the life of the sign is thus always limited. But if the sputtering action is controlled, the life of the tube will be predictable, and maintenance guarantees and costs can be figured safely.

First, electrodes must have a large area exposed for the dissipation of heat. If an electrode runs cool, it will sputter much less violently than if it is hot. Secondly, the electrode must be made of the kind of metal that will resist the sputtering action. Special metals and common ones have been tried. The best electrodes to use for each gas, each pressure, each operating current, and that are affordable to the industry, are known and have been more or less standardized. Third, manufacturers are now making electrodes with ceramic collars at the forward end of the electrode. The ceramic collar won't break down as readily as the metal of the rest of the electrode and so acts as a buffer to prevent much of the sputtering. Finally, the accurate filling of the tube with gas is important since underfilling the tube results in too little a gas reservoir to counter the gas lost to sputtering. Too low a pressure also acts to encourage sputtering since a larger distance between molecules allows molecules to pick up a great deal of speed before impacting each other or the electrodes.

The electrodes can be treated chemically to reduce sputtering by the application of an emissive coating before they are put in the tube. Special patented processes are sometimes used for this purpose. The coating provides a more ready source of free electrons than would the metal alone. If properly processed the tube will start and run at a lower voltage thus reducing the electrical stress on the tube as well as damage due to sputtering. This treatment is sometimes absolutely necessary to ensure reasonable life for a sign. Treated electrodes are especially necessary for helium tubes. Special mechanical features are also incorporated in electrodes to reduce the tendency to sputter. All these features are treated at length in the section on electrodes in the next chapter.

Mechanical requirements of the tubing

The maintenance of the proper gas pressure can be threatened by a more direct action than that of sputtering. If the glass envelope is not completely vacuum tight, air will leak in, and the sign will soon go dead. To assure complete air tightness, the glass should first be mechanically strong and thus not subject to cracks or other breakage. This requires great care in glass blowing, because if the glass is cooled too quickly or unevenly, it will be left in a very brittle and fragile state. Unlike most blown glass produced for other industries, neon sign tubing is not normally stress relieved after the bender works the hot glass. This leaves strain in the glass that can lead to breakage of the signs if exposed to rapid temperature fluctuations or rough handling. Particularly for signs installed out of doors, such strains within the glass will cause trouble, since the sign is then subjected to extremes in temperature.

The second requirement for a vacuum-tight tube is concerned with the lead-in wires that connect the transformer wires with the electrodes. Except for these wires, the whole wall of the tube is made of glass. The leads must necessarily be made of metal, to conduct the current. To make a good joint between glass and wire, the glass must "wet" the wire, that is, adhere to it firmly. Molten glass and wire do not readily cling to each other in this way unless the wire is copper or copper coated.

When wire and glass are heated, as when the wire is sealed on the glass or during the operation of the sign, both glass and wire expand. If the wire tends to expand more than the glass, it will press against the glass with great force. If this force does not crack the glass at once, it will subject it to a great deal of strain which may crack it later, or at least lead to small leaks around the seal. It is important, therefore, that the glass and the wire expand at the same rate as they are heated. If they do so, no internal stress will occur, and the joint will be strong. In practice, a special alloy wire ("dumet" wire) is used for soft glass. This wire has a coefficient of expansion very nearly equal to that of the glass over the entire temperature range to which it will be exposed in manufacture and service. The seal will remain vacuum tight and serviceable if it is thus properly made. For borosilicate glass -- Pyrex® -- tungsten is used for the metal-to-glass seal and often a series of transition glasses are also used that more closely match the tungsten expansion rate.

Electrical protection

Simple as a luminous tube is, it is potentially a very dangerous piece of apparatus. When properly constructed and installed, it presents less danger than an ordinary lamp socket. But if proper precautions are not taken, the high voltage used is definitely dangerous. Since the current is limited to 30 or 60 milliamperes in most cases, the neon sign usually cannot produce a shock of sufficient force to kill an adult. But the shock from a neon sign is powerful enough to overthrow someone, and the resulting fall may easily kill or cripple him or her. Therefore, the possibility of the public coming in contact with the high voltage is far too great a danger to be allowed.

The installations for interior lighting using cold-cathode tubes, especially high-voltage systems, must be made and designed with special care, since the possibility of accidental contact or fire hazards is greater than in exterior sign displays. For such installations it is important that the manufacturer comply with the rules and regulations of governing bodies such as the National Electric Code, or private regulators such as the Underwriters' Laboratories, as well as the local authorities, and follow the procedures outlined by them. In this way, these installations can be made and installed with as little danger as the installations of any other electrical appliance.

The precautions which must be taken involve the thorough insulation of every metallic part in the high voltage circuit. Simply putting the wires and electrodes out of reach of the prying fingers of children and innocent bystanders is not enough, because the wires may come in contact with metal moldings, showcase findings, etc., which will either conduct the high voltage directly to the unsuspecting public or will result in arcing to a nearby conductor resulting in a possible fire. To avoid this, the industry has evolved, with the help of the Underwriters' Laboratories, a very complete set of insulating fittings and connecting wires that completely shield the high-voltage wiring not only from the public but from the weather as well. Protection from weather is essential in outdoor signs.

The wires that lead from the transformer to the electrode leads are thoroughly coated with a high-resistance insulation capable of withstanding more than 15,000 volts. Special insulators of ceramic, Pyrex glass, or plastic are used to connect the electrode and its wiring to the high voltage cable. The connection of the high-voltage cable to the power supply is likewise protected by a ceramic bushing. The entire high-voltage circuit is thus completely enclosed with insulation from start to finish. When so protected, it is actually far less dangerous than the exposed lamp socket in the home.

Operations involved in making a luminous tube

By way of summarizing the foregoing brief introductionof the fundamentals of luminous tubes, the following outline of the construction methods is presented.

A large workbench fitted with a fire-proof covering is required for laying out the patterns and for the actual work of glass bending. A supply of gas andsometimes a means for raising or lowering its pressure is required. An air supply is necessary, usually from a low-pressure, high volume air compressor. A variety of gas burners, or "glass fires," connected to the gas and air supply, is used in heating the glass tubing to the plastic (soft) point, so that it can be bent to the desired shape.

After bending the tubing to the desired shapes, the tube has electrodes sealed onto the two ends and the tube is connected to a pumping system called the neon manifold. A well-maintained pumping system, capable of drawing a good vacuum in the glass tube is needed. Also needed is a supply of inert backfilling gases such as neon and argon (or a custom mix of these two for cold-weather work). In addition to the gases, liquid mercury and a means for injecting it into the tube is required. The manifold should also be equipped with several indicator gauges of good quality for measuringboth the vacuum level in the tube before backfilling, and the accurate pressure of the inert gas fill. A testing coil for testing for vacuum leaks is also handy for troubleshooting both tubes and the manifold.

Finally, supplies of glass of various diameters and appropriately sized electrodes are needed.

Constructing a luminous tube sign

A neon sign usually starts out as a sketch. The sketch must first be made into a full-sized drawing in "tube form" showing the sign as it would appear in bent glass. Various methods can be used to enlarge artwork to the appropriate size. Most neon patterns are still done by hand, although computer methods and optical projection methods are also used. The image, whether it is of letters or graphics, is then reversed and transferred onto heavy paper or heat-resistant cloth. The pattern is reversed because the bender actually works from the back of the sign as the hot glass is shaped onto the pattern.

The glass is then heated in the glass fires and the various bends are made. If the sign is made up of long lengths of tubing, parts may be made separately and the pieces spliced together later. Two electrodes are spliced onto the ends of the tube, one on each end. Normally one end has a tubulated electrode, which is an electrode with a tube in it used for evacuating the air and backfilling the inert gas.

The tube is now attached to the neon manifold via the tubulated electrode. The main vacuum stopcock is opened and the pressure in the tube is reduced to the point where the bombarding transformer can form a discharge through the tube. The heavy bombarder current through the low pressure air quickly heats up the tube. Before turning the bombarder off, the glass heats to about 450°F and the metal electrodes heat to a bright red color. The bombarder is turned off and the main vacuum valve is opened and all the vaporized gases are evacuated.

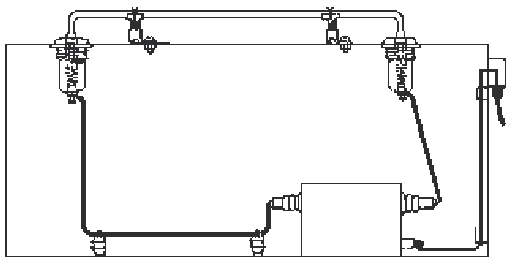

Figure 5 A schematic layout of a box-type neon sign, showing relative location of transformer, mounting parts, cable, tubing,etc.

After thorough evacuation, which is usually determined by the vacuum gauge, the main vacuum valve is closed and the inert gas is carefully ladled in, filling the tube to a pressure dependent on the diameter of the tube. The tubulation is then tipped off with a small hand torch and the sealed tube is ready for aging.

Aging refers to the initial burning period of the tube during which any trace impurities may be absorbed, allowing the tube to age up to its proper color and brilliance. During the aging process, small levels of impurities are cleaned up chemically, although this is not a substitute for proper processing before tipping off the tube. Aging should not take more than a few minutes. If so, the bombarding and pumping processes should be checked.

The tube is now operational but portions of the tube called crossovers, the connections between letters and words that aren't intended to be seen, can be painted out using light blocking paint.

Mounting the tube is a process that largely depends upon the particular installation. However, a typical external neon installation is shown in **Figure 5**. In this type installation a background of metal is made against which the tube glows and which serves to emphasize each letter. The box or housing also serves to mount the transformer.

Standoffs are mounted on the background which hold the glass tube at several points. Two recessed housings or bushings are provided for insulating the electrodes from the metal sign box. The high-voltage cable that connects the electrodes to each other or to the high-voltage power supply is wired internally with care not to run too close together or too close to the grounded metal box. The whole sign is assembled at the shop and shipped with or without the neon installed to the job site. At the job site the sign is secured into place and the primary wiring can be connected to the power supply.

Flashers, time switches, and remote switches can be installed to the primary wiring of the sign. Depending upon the care with which it has been designed and constructed, this type of sign should give three to five years of continuous operation before requiring any service.

The maintenance problem

The limited life of even the best constructed sign should not be forgotten by the sign maker who intends to make money in this business. The sign maker must know how long the signs can be expected to last under various conditions, and the sign must be sold with this in mind. The customer must understand the necessity for periodic maintenance and replacement of worn parts. Sign prices should be calculated to include maintenance for a certain period of time. One of the most difficult business decisions is how long to warrantee a sign and how to handle relations relative to the service on signs.