

In addition to the applications of glow lamps discussed in the previous chapters there are a great number of other applications for this versatile device. This chapter will discuss four major applications. A reference list following the end of the chapter gives a partial list of the many additional glow lamp applications found in the literature.

VOLTAGE REGULATORS

The maintaining voltage of a conducting glow lamp is fairly constant over a relatively wide current range. This characteristic of the glow lamp makes it an ideal component for low cost voltage regulation in circuits where the currents involved do not exceed the normal constant voltage range of the lamp. In general the voltage to be regulated must be the total maintaining voltage of one or a number of glow lamps in series. For best results pre-aged lamps should be used in the following applications.

The most common application for the glow lamp as a voltage regulator is in providing the screen voltage for pentode vacuum tubes. A typical circuit for this application is shown in Figure 4.1.

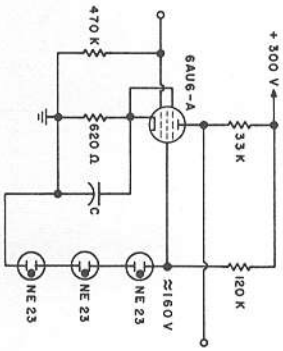


Fig. 4.1. Pentode Amplifier Employing Glow Lamps for Screen Grid Voltage Regulation.

The current drawn by the glow lamp must remain within the operating current range of the lamp over the range of screen grid current drawn by the vacuum tube. In addition, the current drawn by the lamp must be large enough that the lamp will not produce oscillations. Figure 4.2 shows a typical volt-ampere curve covering the normal region of voltage regulation. The curve is for an NE-23 lamp.

When a glow lamp is used as a voltage regulator the voltage will vary slightly as a function of temperature. Figure 4.3 shows a typical curve of lamp voltage versus temperature for an NE-23 lamp operating at the rated lamp current of

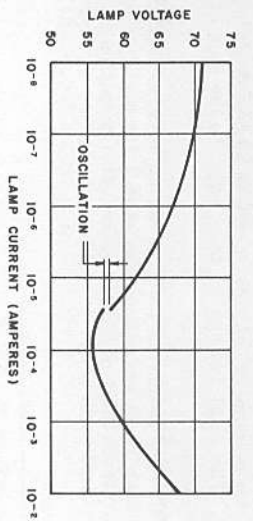


Fig. 4.2. Volt-Ampere Characteristic Curve for Aged NE-23 Glow Lamp.

.3 milliampere. The maintaining voltage of the NE-23 and related low voltage types has a decreasing temperature characteristic of about 40 millivolts per degree Centigrade when operating at the rated current of the lamp.

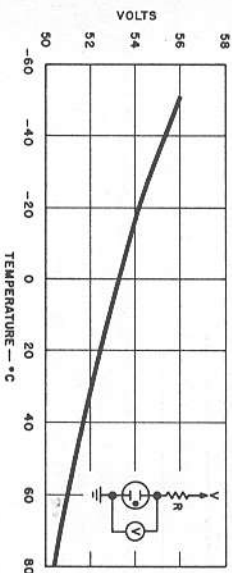


Fig. 4.3. Typical Temperature Response of Glow Lamp Voltage Regulator.

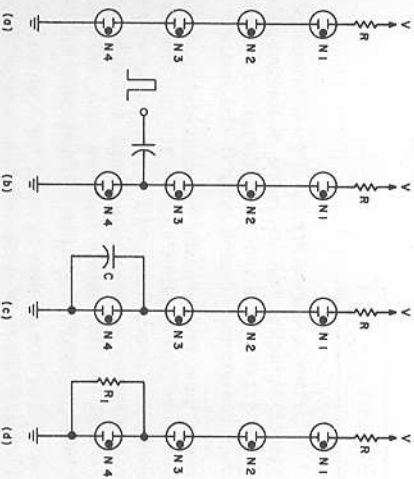


Fig. 4.4. Starting Methods for Glow Lamp Regulators.

By placing a large number of glow lamps in series, high regulated voltages may be obtained. The total voltage is then equal to the sum of the maintaining voltages of the lamps.

In order to fire the lamps in a series string several methods may be used. If the supply voltage is in excess of the total firing voltages of the lamps then the lamps will fire when the voltage is applied. This situation is shown in Figure 4.4a.

For this case then:

$$V > V_{F1} + V_{F2} + V_{F3} + V_{F4} \quad (4.1)$$

By using a triggering pulse to fire the lamps a lower supply voltage is required. An application showing this method is shown in Figure 4.4b. The amplitude of the triggering pulse must be large enough to fire the lower lamp. Once this lamp is fired the voltage across it drops to the maintaining voltage of the lamp and thus places a higher voltage across the other three lamps.

Then in order that the other three lamps will fire:

$$V > V_{F1} + V_{F2} + V_{F3} + V_{M4} \quad (4.2)$$

A third method for initiating conduction in the lamps is shown in Figure 4.4c. When the supply voltage is applied to the network, capacitor C acts as a short circuit so that the total voltage is placed across lamps N1, N2, and N3. The supply voltage must be large enough to cause these three lamps to fire.

Therefore:

$$V > V_{F1} + V_{F2} + V_{F3} \quad (4.3)$$

After the lamps have fired, the capacitor begins to charge up through the conducting lamps with the voltage across N4 rising. When this voltage reaches the firing voltage of N4 it will fire. This places an additional requirement on the supply voltage.

$$V > V_{M1} + V_{M2} + V_{M3} + V_{F4} \quad (4.4)$$

Another method of starting a series string of glow lamps is the use of a high (10 megohms) resistance bridging one or more of the lamps. This is shown in Figure 4.4d. The voltage across each lamp is determined by the capacity as well as the 'off' or leakage resistance of each lamp in the string.

This bridging resistance reduces the net resistance of the bridged lamps leaving a larger portion of the applied voltage for the rest of the lamps in the string. If proper values are used, there will be sufficient voltage to break down these lamps. The voltage drop across these lamps will then be the sum of their maintaining voltages, and the difference between this and the supplied voltage must now be large enough to break down the bridged lamp or lamps.

Larger strings of series lamps may be used for high voltage regulation with firing of the lamps initiated by applications of these firing techniques.

Pre-aged lamps such as the NE-76, NE-80, NE-81, or NE-68 work well in voltage regulation circuits. For higher current applications, use of the NE-86 or NE-83 should be considered.

VOLTAGE LEVEL DETECTORS

The glow lamp has a very high input resistance prior to firing and after firing gives a visual indication that the lamp is conducting. Both of these characteristics make the glow lamp suitable to various applications as voltage level detectors. Practically any number of glow lamps may be placed in a series string so that very high voltages may be detected. The current required to give a visual indication is very low so that even after the lamps have fired, the detector circuit may have a negligible loading effect.

In general the voltage required to fire a glow lamp voltage detector will be the sum of the firing voltages of the lamps in the series string, assuming leakage resistances are similar. If higher resolution is required a variable bias voltage may be provided such as shown in Figure 4.5. By switching lamps in or out of the circuit a wide range of voltages may be detected.

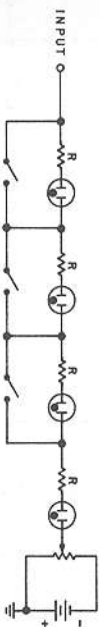


Fig. 4.5. Variable Voltage Level Detector.

Another type of circuit which acts as a variable voltage detector is shown in Figure 4.6a. By varying the potentiometer the circuit may be adjusted to indicate any voltage greater than the firing voltage of the lamp. A variation of this circuit shown in Figure 4.6b will detect two voltage levels. N1 will fire when its firing voltage is reached and N2 will fire at a voltage dependant upon the input voltage and the ratios of R1 and R2.

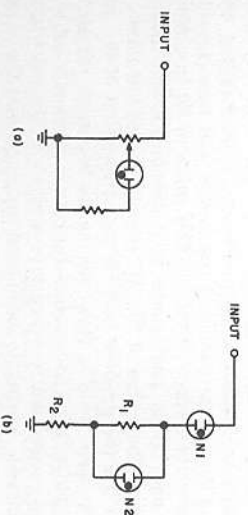


Fig. 4.6. Voltage Level Detectors.

These voltage indicating circuits may be used equally well for both DC voltages and peak AC voltages at low frequencies.

Several references at the end of the chapter give specific applications of the glow lamp voltage level detector.

COUPLING NETWORKS

The neon glow lamp can be operated in a condition where the DC resistance is much larger than the AC impedance of the lamp. This is achieved by superimposing an AC signal across a lamp conducting direct current. The DC bias provides a relatively fixed voltage drop across the lamp. Under this condition a DC component of an input signal will be attenuated much more than the AC component. This property of the glow lamp makes it an ideal device for lowering the DC level in direct coupling of vacuum tube stages.

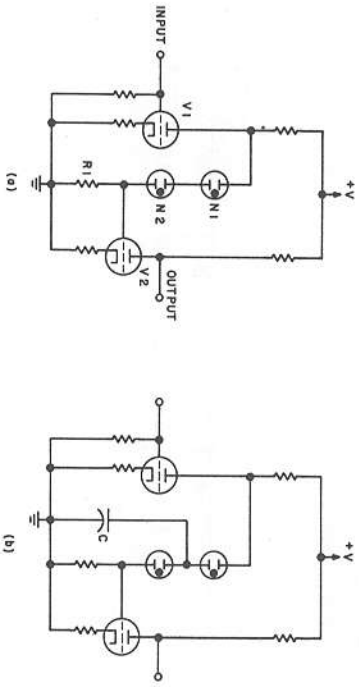


Fig. 4.7. Direct Coupled Circuits Employing Glow Lamps.

Figure 4.7a shows the basic configuration for direct coupling with glow lamps. The plate voltage of V1 must be such that the lamps will fire. In selecting resistor R₁ several considerations must be made. The value of R₁ in conjunction with the plate voltage and equivalent resistance will determine the value of DC current in the lamp and thus the value of the AC impedance of the lamp. In addition the larger the value of R₁ the greater will be the proportion of the AC plate voltage of V1 seen at the grid of V2. However as R₁ becomes larger the DC voltage component on the grid of V2 also becomes larger, thus requiring a larger cathode resistor for V2 and consequently more degeneration of the AC signal. The circuit components chosen will normally be a compromise and the largest AC gain of the amplifier is best found by a trial-and-error approach.

The plate voltage of V1 may be operated slightly less than the combined firing voltages of lamps N1 and N2 when a capacitor is added as shown in Figure 4.7b. This capacitor serves the same purpose as for the voltage regulator circuit of Figure 4.4c and the same design conditions apply. The value of the capacitor may be on the order of only 25 pf so that it will offer a high impedance to the AC signal.

The impedance presented by the glow lamps in a direct coupled circuit varies as a function of the DC current and the frequency of the input signal. At frequencies below about 1000 cps the impedance of the lamp is essentially resistive with the magnitude of the resistance depending upon the slope of the volt-ampere characteristic of the lamp at the particular operating point.

As the frequency becomes higher the lamp becomes inductive so that for frequencies higher than about 1000 cps the lamp may be represented by an AC equivalent circuit of a resistance in series with an inductance. Both the value of the resistance and the inductive reactance increase with increasing frequency. In addition the impedance varies with the DC lamp current. Figure 4.8 is a plot of the effective resistance and reactance of an NE-23 glow lamp operating at the rated current of .3 milliamper. The input AC signal was 1 volt RMS.

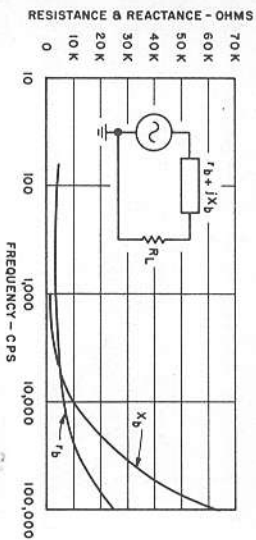


Fig. 4.8. Effective Resistance and Reactance of NE-23 Glow Lamp Operating in a Coupling Circuit at 0.3 Milliamper DC.

The effect of this lamp impedance is to introduce an attenuation and a phase shift in the signal as the frequency of the signal is increased. To reduce this effect and hence increase the high frequency response of a glow lamp coupled amplifier a capacitor may be placed across the glow lamps. A typical circuit is shown in Figure 4.9 with the response curves shown in Figure 4.10 for both conditions - with and without a bypass capacitor. The low frequency voltage gain of the circuit is 48.

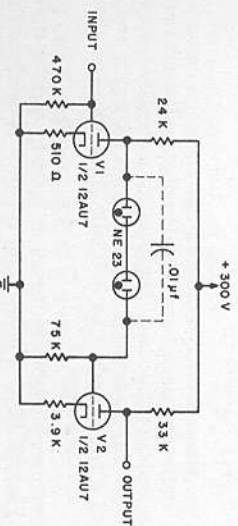


Fig. 4.9. Glow Lamp Coupled Amplifier.

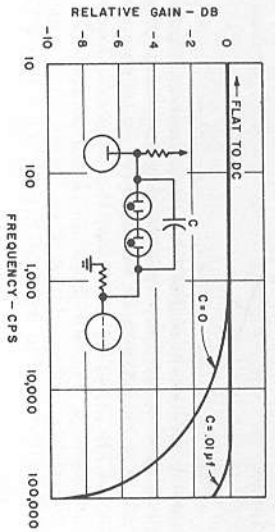


Fig. 4.10. Amplitude Response of Glow Lamp Coupled Amplifier.

Any number of glow lamps may be used in a direct coupled stage provided that the applied DC voltage is sufficient to fire the lamps. The magnitude of the maximum AC signal depends on the degree of distortion permissible. Normally signal amplitudes of several volts will have little distortion.

THE GLOW LAMP AND PHOTOCONDUCTIVE DEVICES

An increasing number of applications are being found for the glow lamp in conjunction with photoconductive devices. Among these photoconductive devices are the cadmium sulfide and cadmium selenide photoconductors and photosensitive semiconductor devices. The spectral response and light intensity of many of these devices is compatible with the light output of the neon glow lamp. In addition the low power consumption and speed of response of the glow lamp makes it a desirable light source. Either standard brightness or high brightness glow lamps may be used with photoconductive devices.

Photoconductive Cells

A photoconductive cell, or photocell, is a device whose resistance varies with the amount of light radiation impinging upon its surface. Although many types of photoconductive materials are in use, or under development, cadmium sulfide and cadmium selenide are presently the most widely used. Each offer certain advantages over the other.

The spectral response of the cadmium sulfide photocell normally peaks around 5500 Angstroms while the cadmium selenide photocell peaks around 7000 Angstroms. Thus the cadmium selenide photocell is normally better matched to the neon glow lamp spectral emissivity. However, variations in the mix, materials, and processing of a photoconductive cell will allow its peak spectral sensitivity to be varied over a wide range.

Photocells vary considerably in terms of light-to-dark resistance ratios and in their value of resistance at a given light level. A typical cadmium sulfide cell may have a light-to-dark resistance ratio of 1,000,000 or more. The resistance of a photocell is normally specified at one or more levels of illumination. The resistance of a photocell is a very nearly logarithmically linear as a function of the illumination. The resistance decreases with increasing illumination.

Sensitivity of photoconductors varies with temperature; cadmium sulfide, however, is much more temperature-stable than cadmium selenide. In fact, the major disadvantage of cadmium selenide cells is their susceptibility to temperature variations.

Photocells have two response speeds; turn-on response and turn-off response. In general the response speed of cadmium sulfide cells will average 100 milliseconds. The response speed of cadmium selenide cells is approximately 10 milliseconds. Response speeds of both types are dependent on the previous state of the device and the illumination level. Hence in photocell-glow lamp combinations the speed of response will normally be limited by the photocell.

Several glow lamp-photocell circuits have been given in previous sections of this book. In addition other applications are described in the references listed at the end of the chapter. The most common use of the glow lamp-photocell combination has been in memory and logic circuits. In these applications the input circuit is isolated from the output circuit — an advantage not obtained by most memory devices. In addition a single photocell output circuit may be actuated by a number of glow lamp sources or one lamp may actuate several photocells.

The glow lamp-photocell combination is best used where the resistance of the photocell is switched from a very high resistance to a low resistance depending upon whether the glow lamp is conducting or not. In addition the resistance of the photocell may be varied by varying the light output or position of the glow lamp. This provides a control where there is electrical isolation between the control circuit and the receiving circuit.

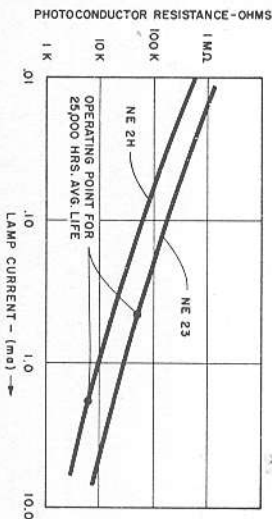


Fig. 4.11. G. E. B-425 Photoconductor Resistance vs Lamp Current — NE-23 and NE-2H (Lamp Located 1.5" From Cell)

Figure 4.11 is a typical plot of photocell resistance as a function of lamp current in the NE-23 standard brightness and the NE-2H high brightness glow lamps. The lamp is located about 1.5 inches from the photocell in a dark enclosure. The dark resistance of this photocell was in excess of 10 megohms, and other types are available with even higher resistance.

MISCELLANEOUS APPLICATIONS

A variation of the light indicator described in Chapter Two is a circuit consisting of a photoconductor in parallel with a glow lamp. At a specific light level the lamp will fire, providing visual indication.

This same principle can be used in the design of a temperature indicator, which utilizes a thermistor in parallel with a glow lamp. Here a visual indication

is provided at a specified temperature by the firing of the glow lamp, or a photo-conductor can be used to sense the firing and actuate external circuitry.

Likewise, a humidity sensing circuit can utilize a humistor as a variable resistance in parallel with the glow lamp. Humistor resistances typically decrease with an increase in humidity. Once again, the firing of the glow lamp at a specific humidity can be used for visual indication or to actuate external circuits.

Since consistent firing voltage is required for the above applications the use of a pre-aged lamp such as the NE-76 is recommended.

REFERENCE LIST

- "The Application of the Gaseous Discharge Tube to Problems of Voltage Regulation", *Journal of Scientific Instruments*, vol 14, May 1937, pp 161-164.
- "Relaxation Circuit Measures Radiant Energy", *A. Sager, Electronics*, vol 10, July 1937, p 29.
- "Gas-Tube Coupling for D-C Amplifiers", *F. Jannone and H. Baller, Electronics*, vol 19, October 1946, pp 106-107.
- "Novel Application for Neon Diodes", *I. Gottlieb, Electronics*, January 1951, pp 180-186.
- "Direct Coupled Control Circuit not Requiring Cascaded Power Supplies or Special Biasing Voltages", *J. Degeleman, Review of Scientific Instruments*, vol 22, November 1951, p 847.
- "R-F Burst Actuate Gas Tube Switch", *H.J. Geisler, Electronics*, February 1952, pp 104-105.
- "Neon Lamps as Circuit Elements", *W.R. Kincheloe, Jr., Technical Report No. 10, Stanford University Electronics Research Laboratory*, May 26, 1952.
- "Neon Indicator Tubes as Quantitative Detectors in Photometry", *British Journal of Applied Physics*, vol 4, August 1953, pp 243-247.
- "Cold Cathode Tubes for Transmission of Audio Frequency Signals", *Bell System Technical Journal*, vol 32, November 1953, pp 1371-1391.
- "Relaxation Oscillations in Voltage-Regulator Tubes", *P.L. Edwards, Proc. I.R.E.*, vol 41, December 1953, pp 1756-1760.
- "Transient Response of Glow Discharges with Applications", *R.S. Mackay and H.D. Morris, Proceedings of the I.R.E.*, vol 42, June 1954, pp 961-964.
- "Electrically Variable Gas-Dielectric Capacitor", *J.F. Gordon, Electronics*, January 1956, pp 158-160.
- "Alarm System Uses Gated Neon Warbler", *R.L. Ives, Electronics (Engineering Issue)*, May 23, 1958, pp 74-77.
- "Electronic Level Indicators for Tape Recorders", *H. Burslein, Radio and TV News*, December 1958, p 42.
- "Kill Commercials Fast", *O. Relling, Radio-Electronics*, June 1959, pp 32-33.
- "9 Uses for the 9-Cent Wonder", *R.B. Kuehn, CQ*, August 1959, p 40.
- "Oscillator Control Circuit Uses Neon Bulb", *J. Tewksbury, Electronics*, January 26, 1962, p 52.
- "Neon Tube Serves as Tuning Indicator for F.M. Receiver", *M.W. Edgerton, Jr., Electronic Design*, March 15, 1962.
- "Neon Lamp Leakage Tester", *J.A. Hastings, Electronics World*, May 1962, p 74.
- "Neon Lamps Make a Voltage Indicator", *L.E. Greenlee, Radio-Electronics*, September 1962, pp 98-99.
- "Neon Lamps Provide Simple Voltage and Frequency Indication", *J. DeMatteo, M. Weiner, R. Grant, Electrical Design News*, September 1962, p 41.

GLOW LAMP TEST METHODS

CHAPTER

5

TEST CIRCUITS

The glow lamp is a very high resistance device when in the non-conducting state and as such requires special care when attempts are made to measure its parameters. The lamp characteristics of value to the circuit designer are the firing voltage, the maintaining voltage and the extinguishing voltage. The values of these parameters change as a function of frequency and associated circuit components so that the type and accuracy of the measurement depends upon the requirement. For normal circuit component use the tests are usually made easily and quickly.

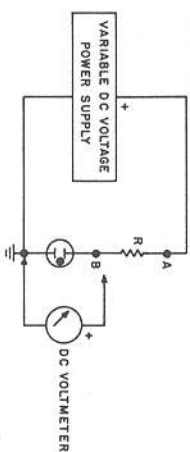


Fig. 5.1. Test Circuit for Determining Lamp DC Voltage Characteristics.

Figure 5.1 shows a test setup which may be used for making approximate measurements of the lamp parameters. A voltmeter with a resistance of 20,000 ohms per volt is sufficient to prevent loading of the lamp circuit.

With the voltage initially at a value below the expected firing voltage of the lamp the voltmeter lead is placed at point A. The supply voltage is then slowly raised until the lamp just fires which is indicated visually by the cathode glow. The reading of the voltmeter will now give the value of the firing voltage of the lamp under test. The DC voltmeter probe may now be moved to point B and the maintaining voltage will be indicated. If it is desired to know the maintaining voltage at a particular value of current the supply voltage may be varied until the proper current is obtained — assuming that the resistance is such as to permit the desired amount of current to flow. The approximate value of current may be obtained by measuring the voltages at points A and B. The current is then determined by the equation $I = \frac{V_A - V_B}{R}$.

After the maintaining voltage is measured the voltmeter probe may be re-turned to point A. The voltage is then slowly decreased until the lamp current abruptly ceases. The voltage at this point is the extinguishing voltage for the given value of resistance R.

Care must be taken in choosing the value of resistance R in the measuring circuit since large values of R in conjunction with stray capacitance may cause the circuit to oscillate once the lamp has fired.

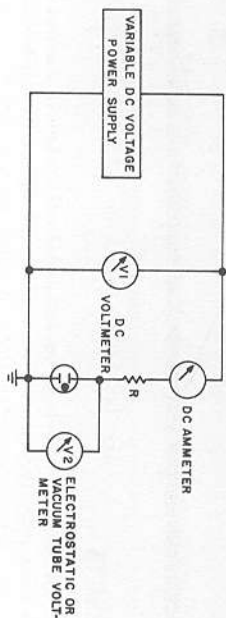


Fig. 5.2. Test Circuit for Determining Lamp DC Voltage Characteristics.

Another testing circuit is shown in Figure 5.2. Two voltmeters may be used to avoid changing leads. Voltmeter V_2 which is placed across the glow lamp should be of the electrostatic or vacuum-tube type of voltmeter with an input resistance greater than ten megohms. If an electrostatic voltmeter is used a resistance of about 10 to 30 megohms should be placed in series with the meter to suppress a tendency of the circuit to oscillate due to the meter's capacity. Voltmeter V_1 need not have a very high input resistance as its shunting effect on the test circuit is negligible.

The firing voltage is determined by slowly raising the supply voltage and noting the value of voltage measured on voltmeter V_1 when the lamp just begins to glow or the ammeter gives an indication of conduction through the lamp. Current should normally be close to the lamp's rated value. The internal resistance of this ammeter should be less than one percent of the value of R .

With the lamp operating at the desired current as indicated by the ammeter the maintaining voltage may be read by voltmeter V_2 . To measure the extinguishing voltage the supply voltage is decreased slowly and the voltage is read on voltmeter V_1 when the lamp ceases conduction.

It is often desirable to measure the dynamic values of firing and extinguishing voltage for a circuit in operation; for example, a sawtooth oscillator. Figure 5.3 shows a circuit which may be used to effectively isolate the glow lamp circuit from the test circuit. The vacuum tube cathode follower stage has essentially an infinite resistance at the grid input so that there is negligible loading on the lamp circuit. In addition the input capacitance of the cathode follower is very low so that the total capacitance shunting the glow lamp is on the order of only a few micro-micro-farads.

The transfer characteristic of the cathode follower may be determined by varying a DC voltage on the grid and measuring the corresponding output cathode voltage. An alternate method of obtaining the approximate transfer function of the cathode follower is to drive the grid with a small sine wave signal superimposed on a DC bias of perhaps 50 volts as shown in Figure 5.4. The DC transfer characteristic of the cathode follower is then approximately:

$$V_o = AV_1 + E_{k_0} \quad (5.1)$$

where A is the small signal AC gain (less than unity) and E_{k_0} is the DC cathode voltage measured with the grid grounded.

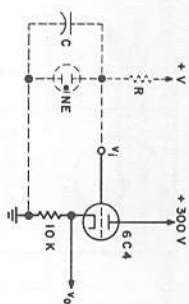


Fig. 5.3. Test Circuit for Determining Dynamic Lamp Characteristics with Lamp Circuit Isolated from Output.

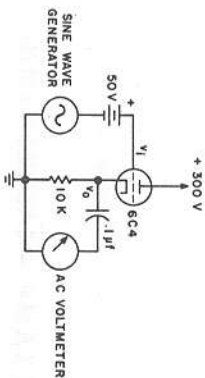


Fig. 5.4. Test Circuit for Determining Approximate Transfer Function of Cathode Follower.

After the transfer function of the cathode follower has been determined the dynamic firing and extinguishing voltages of the glow lamp circuit may be measured by using a calibrated DC oscilloscope on the output.

The cathode follower circuit also provides another means of measuring the DC firing and maintaining voltages of a glow lamp. If an oscilloscope is used which has an output sawtooth sweep available at a very low frequency and a voltage greater than 100 volts this slowly rising voltage may be used as a variable supply voltage for a glow lamp with a series resistor as shown in Figure 5.5. By placing the output of the cathode follower to the vertical input of the DC oscilloscope voltages proportional to breakdown potential and the maintaining voltage of the lamp may be measured from the scope presentation. The actual values of the breakdown voltage and the maintaining voltage may then be determined by using the equation for the transfer function of the cathode follower.

This method of determining the operating characteristics of lamps is particularly useful when large numbers of lamps are to be measured.

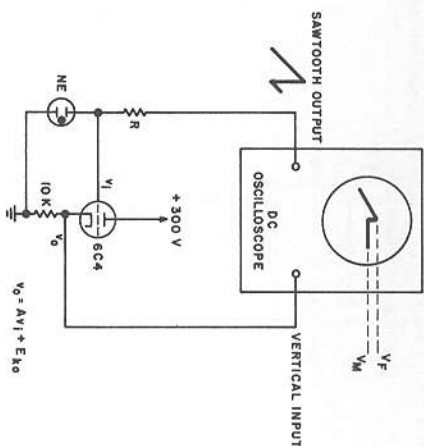


Fig. 5.5. Alternate Method of Determining Firing and Maintaining Voltages of Neon Glow Lamps.

CONDITIONS FOR LAMP MEASUREMENTS

In determining the parameters of a glow lamp care should be taken to provide the proper environment. Recommended practices are:**

1. Lamp measurements should be made at room temperature of about 25°C.
2. For measurements to be made in light the measurement should be made in an unobstructed ambient illumination of 5 to 50 footcandles. The lamp which is to be tested should be operated in the conducting state for a short period prior to measurement.
3. In the case where it is desired to measure a lamp in total darkness the lamp should be inoperative for a period of at least 24 hours immediately prior to testing and the enclosure should be light-tight.
4. Under conditions of life testing of glow lamps the lamps should be operated at the specified design current while also observing the correct polarity of the lamp when indicated.
5. Life testing of glow lamps should be interrupted once a day.

Specific applications may require testing procedures which deviate from recommended practices.

**"Measurement of Glow Lamps", A.S.A., 10 East 40th Street, New York 16, New York.

In placing a lamp in a testing circuit care should be taken to avoid the capacitive effect of having other objects in contact with the lamp. These objects, such as metal plates and shields, should be kept at least six inches away from the lamp to be tested. In addition, touching the lamp during testing should be avoided as errors will probably result. Proper shielding may be required to minimize the effects of stray fields and radio-frequency radiation which have a decided effect upon the firing voltage of the lamp.