Neon Glow Lamps: Alternative Applications

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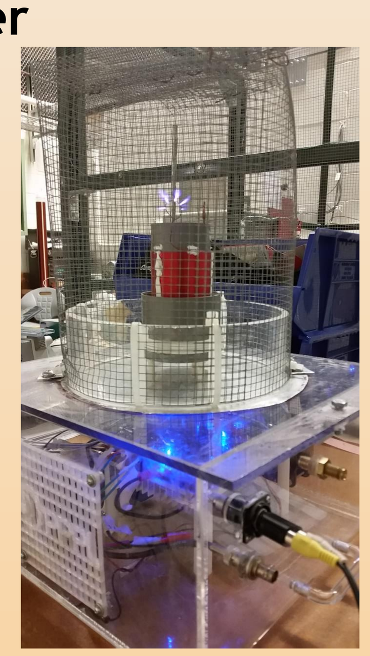
Objectives

- **Examine the discharge curves of various neon glow lamps and develop an electronic oscillator**
- **Understand negative differential resistance and design an incandescent bulb blinker with a glow discharge and oscillator circuit**
- **Obtain proof of principle for a plasma microphone by designing equipment to transduce audio to electronic signals via brush discharge plasma speaker**

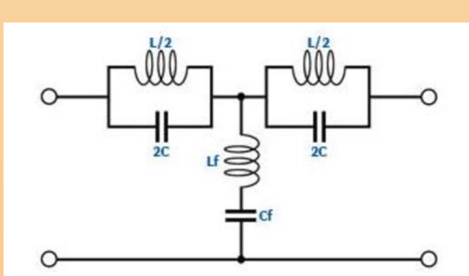
Plasma Speaker

The proof of principle for a plasma microphone was obtained using the existing plasma speaker, which modulates a 4 MHz AC brush discharge with an electronic signal that generates the audio. For the plasma microphone experiment, the audio modulation was disabled, and a sinusoidal sound wave propagated through the brush discharge. Theoretically the pressure perturbation of the sound wave modifies the discharge's resistivity. A short monopole antenna was used to receive EM emission from the discharge.



Science Education Lab Plasma Speaker in operation

Due to the high frequencies, several filters were necessary, including a customer LC filter. After significant effort to suppress high-frequency noise, the transduced sound wave became visible on a digital oscilloscope connected to the antenna.



Resonant LC notch filter: $L = 15\ \mu H$, $C = 55pF$, $L_f = 30\ \mu H$, $Cf = 67pF$

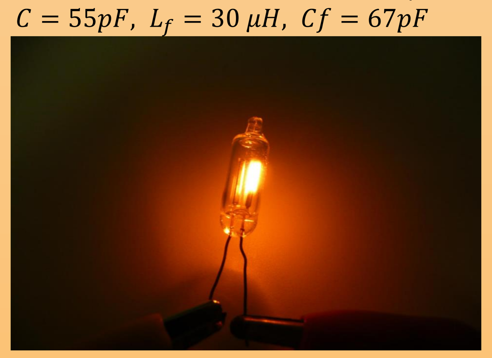


Figure 1

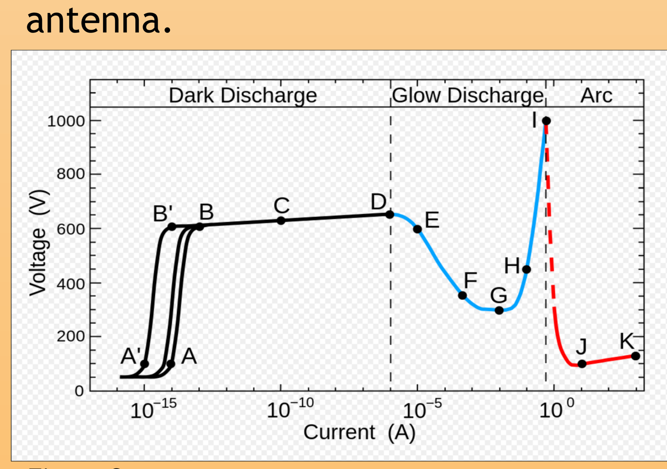


Figure 2

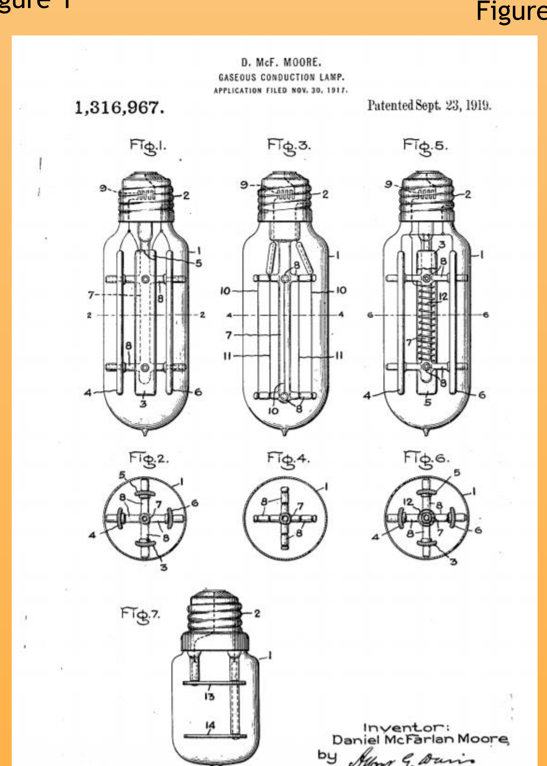
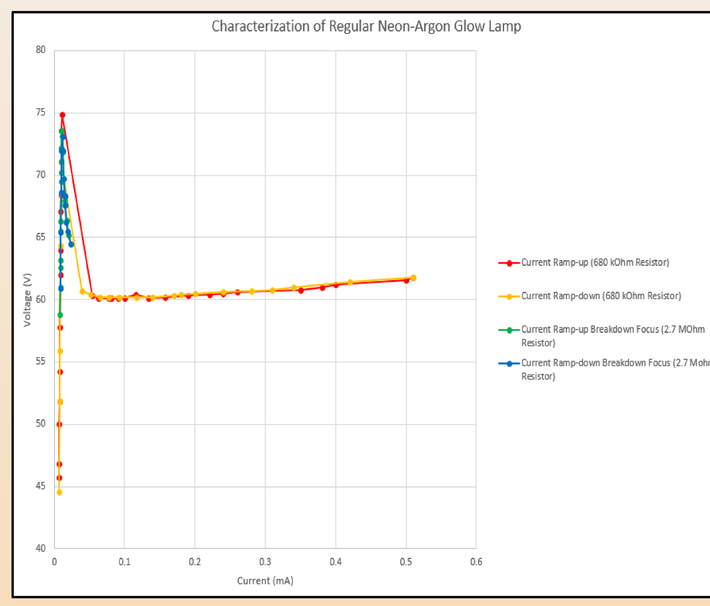


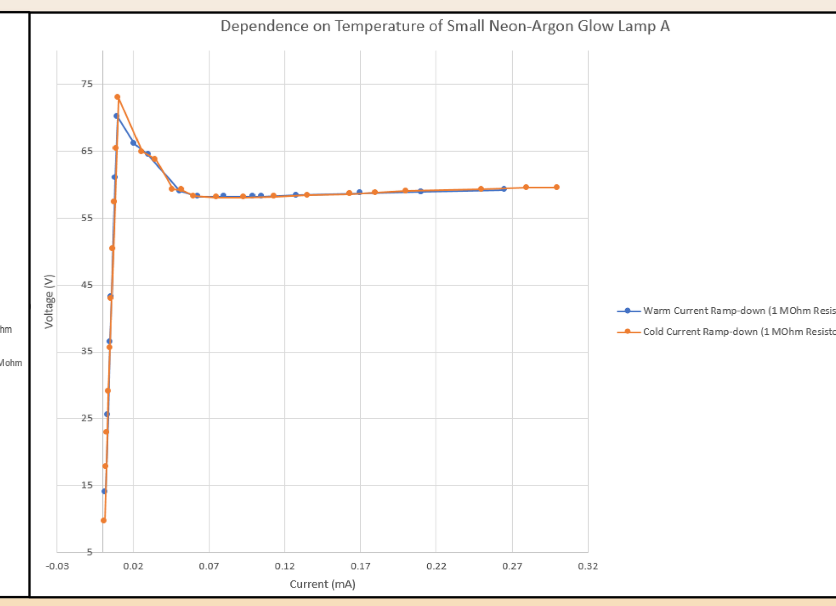
Figure 3

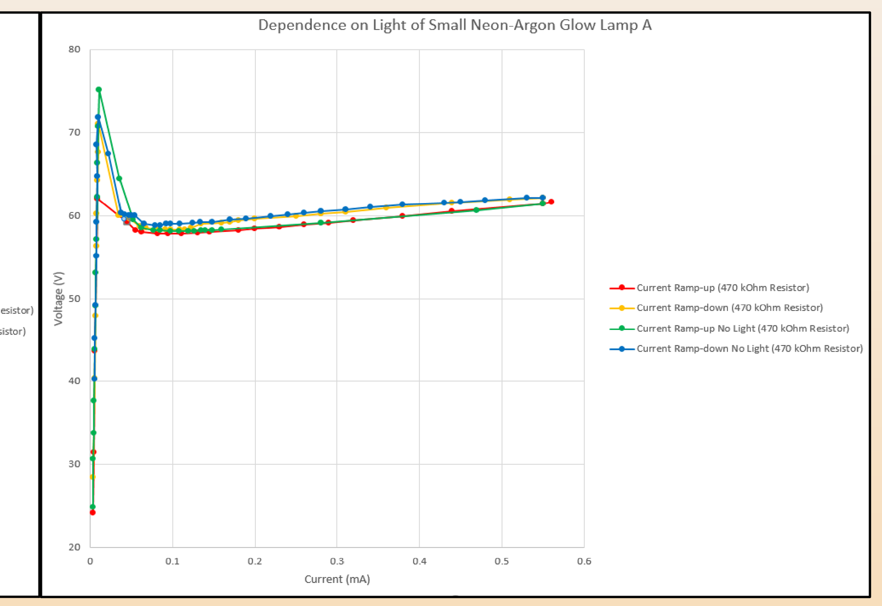
- Figure 1: a neon glow lamp, as designed by Daniel McFarlan Moore in 1917. The low pressure gas inside the bulb was originally neon but was later changed to the Penning mixture, 99.5% neon, 0.5% argon, which lowers the breakdown voltage
- Figure 2: a glow discharge graph. A → B: breakdown voltage needed for discharge, B → D: Townsend discharge, D: breakdown, D → G: subnormal glow, and G → I abnormal glow
- Fig. 3: Daniel McFarlan Moore's patent

Characterizations of Various Neon Glow Lamps

A glow discharge plasma could potentially be a good transducer for a plasma microphone. Several types of neon glow lamps, a common type of glow discharge that have many advantages, were therefore considered for this application.



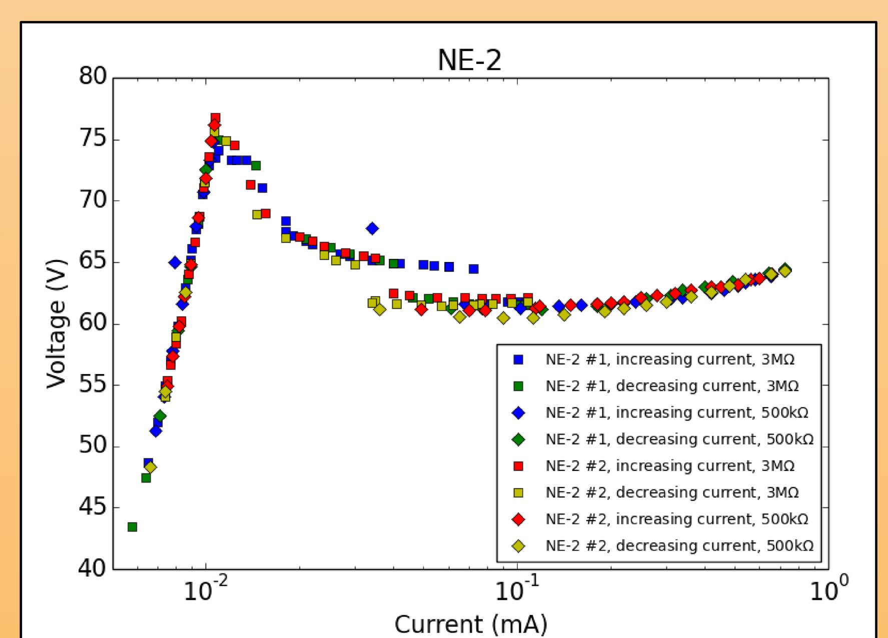


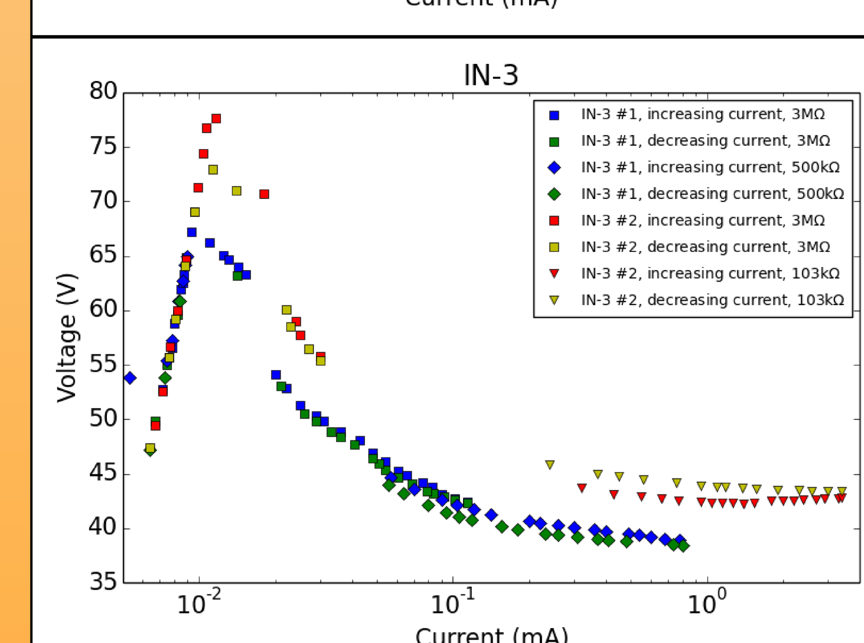


The graph above shows the data for a standard NE-2 glow lamp. Voltage is taken as a function of current. Data was taken both for when current was increased and decreased. The difference in breakdown voltage and extinction voltage is noted. The value of the resistor was changed in order to gain resolution for different areas of the discharge curve. For the breakdown and subnormal glow regions, high resistances were chosen to limit current through the circuit. To show the beginning of the abnormal regime, a small resistor was chosen. The data is highly consistent, indicating good conformity in performance for NE-2 bulbs and smaller.

Top graph: Data was taken using two different NE-2 lamps and two different resistors, a low value of $500\ k\Omega$ and a high value of $3\ M\Omega$. The low value resistor was chosen so that the beginning of the abnormal regime could be observed, which occurs as the current approaches 1 mA. The high value resistor was used to limit current so that high resolution data could be obtained for the breakdown regime. It should be noted that the two different lamps perform very similarly. There is little deviation in the data. Some deviation may be attributed to small manufacturing defects, exacerbated by higher currents.

The graph above shows the data for a smaller NE-1 glow lamp. Data was taken for current and voltage after the lamp had time to warm up, then the circuit was allowed to cool and data was taken in order to determine any dependence on temperature. The percent difference between the cold and warm extinction voltages is 4.1%, enough to note that in a cold circuit, the extinction voltage may be slightly higher, but not by a statistically significant amount.





The graph above shows the data for the same small lamp. Data was taken in the same manner, with the bulb uncovered and with the bulb covered with black electrical tape. Since breakdown can be triggered by a number of sources, blocking light is an effective way to assess the lamp's dependence on environment. The percent difference for the breakdown voltage with light and with no light is 19% which indicates a dependence on light to trigger breakdown. The percent difference for the extinction voltage with and without light is 1.1%, indicating no statistically significant dependence on light for the extinction voltage, which is expected.

Bottom graph: Data was taken using two IN-3 lamps with the same two resistors as were used to test the NE-2 lamps. There is clear disparity between the performances of the two Russian neon glow lamps, which is most probably attributed to manufacturing irregularities and poor quality control. It could also be a result of the internal structure; there is a square metal cathode and a wire rectangle anode in the IN-3, which may result in performances differences if polarized incorrectly or if they are not identically separated across bulbs. The NE-2 lamps have two metal rods. There is a wide spread in data and a hysteresis should be noted. It is also clear that the IN-3 lamp is capable of operating at higher currents while remaining in the subnormal regime, where the Pearson-Anson effect is observed, as evidenced by the lack of upturning on the tail of the blue and green data points.

Electronic Oscillators

Stephen Pearson and Horatio Anson discovered an electronic oscillator in 1922. Their circuit design involved a neon glow lamp in parallel with a capacitor preceded in series by a current limiting resistor. The current will charge the capacitor until the breakdown voltage is reached, at which point the resistance of the bulb becomes less than that of the capacitor, and it discharges across the bulb so that it flashes. The capacitor then starts charging again (Fig 1). The time constant of the circuit is set by the capacitance, resistance, and breakdown and extinction voltages. When an incandescent bulb or LED is connected in series with the neon glow lamp, it acts as a switch. Due to the operating limits on incandescent bulbs, a power transformer must to used to decrease the voltage and increase the current (Fig 2).

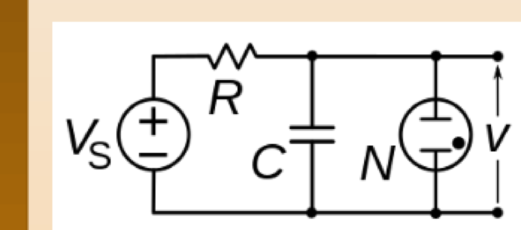


Figure 1

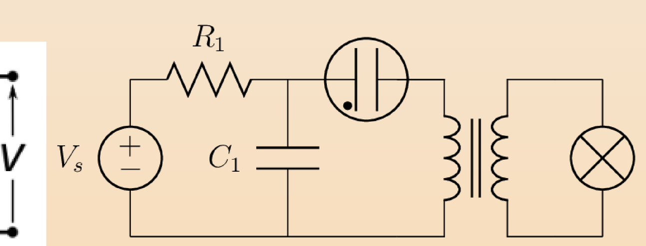


Figure 2

The NE-2 lamp was used as a switch in an incandescent bulb blinker circuit. The current required for the lamp to flash is insufficient to light the bulb, so a transformer was obtained. Due to core limitations and saturation issues, the transformer was unable to function correctly and the bulb did not light consistently. A different apparatus was acquired, a glow discharge tube (Fig 3). The discharge tube has a number of advantages over NE-2s.

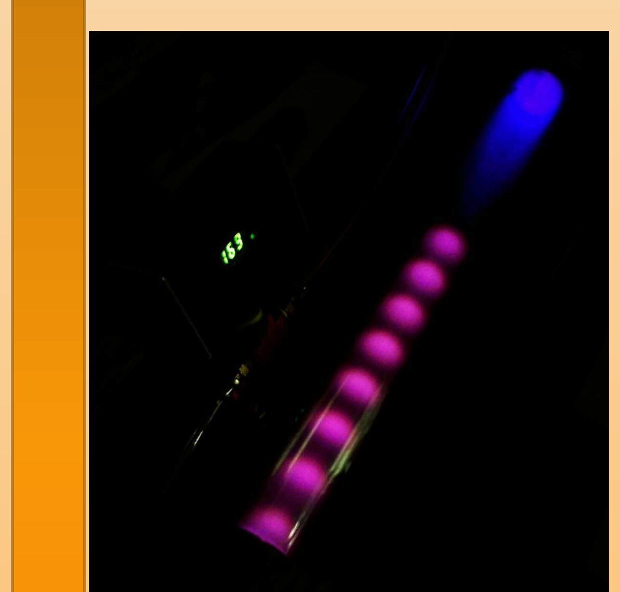


Figure 3: A Science Education Lab glow discharge tube

It has larger electrode plates, which allow higher current to pass, it operates at higher voltages, and its electrodes are variable, allowing for a higher breakdown voltage to be set while remaining in the correct operating parameters. The transformer's saturation issues persisted by not at degrees detrimental to the experiment.

Further Work

The limitations of the plasma speaker make it impractical as a plasma microphone. It is probable that a neon glow lamp would work well as a contact microphone for high frequencies. These NE-2s are ubiquitous, quiescent, and operate at low voltage. They were very popular prior to LEDs and remain common today as indicator lights, in power strips for example. The Russian design neon glow lamp, the IN-3, has the ability to operate in the beginning of the subnormal regime before sputtering and arcing at much higher currents, which make it an excellent candidate for an incandescent bulb blinker.

Acknowledgements

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