GAS TRIODE, TEL 532

The Gas Triode consists essentially of a filament and a circular plate, between and parallel to which is separately mounted a grid.

These are contained within a clear glass bulb in which there is an helium atmosphere at low pressure. The filament is pure tungsten wire, mounted on two leads connected to 4 mm. sockets in a plastics cap on the neck. Connection to the plate is by a 4 mm plug mounted on a plastics top cap, whilst connection to the grid is by a similar plug mounted on one of the plastics side-caps.

This form of construction corresponds with the conventional Triode symbol and provides a simple planar arrangement. The construction is in fact identical to that of the Vacuum Planar Triode, TEL 521, and differs only by the presence of helium in the bulb.

Operating Specification: — Maximum filament voltage 7.5V 4A

Maximum plate current 60mA

Cold cathode striking voltage 280-320V

Notes:

1) Because of thermal conduction by the helium, the temperature of the filament at the same operating voltage is lower in the Gas Triode than in the vacuum version.

2) The Gas Triode can conduct much higher currents than the vacuum tube, so that power supplies should be adequate and suitably fused against overload.

3) Operation for long periods with a 'heavy' gas discharge can lead to sputtering of the electrode material on to the bulb, and darken it.

RECOMMENDED EXPERIMENTS.

Production of cathode rays and the 'discovery' of the electron, which form the subject of Series A experiments, can be introduced by trying to liberate electrical charges from a heated wire by 'evaporation'. The experiment when made in air is ambiguous because both positive and negative charges are detectable; by working in a vacuum only, the negative charge is liberated and experiments eventually lead to establishment of the electron and its properties.

Attention can now be turned to the positive charge and the possibility that it is associated with the mass of the atom. The means to release the positive charge revealed in the experiment in air are available in a triode when filled with gas, the extra electrode permitting investigation of the processes involved. These can be studied by measuring the mutual characteristics of the Gas Triode (see Planar Triode Experiment 20). Alternatively, since introduction of the gas is the only parameter changed, the effects observed can be explained in terms of collision processes between the gas atoms and the stream of electrons.

EXPERIMENT 1 (SERIES B) THE I_a/V_a CHARACTERISTIC WHEN CONNECTED AS A DIODE

Connect the Gas Triode into the circuit of Figure 1 and observe the following:

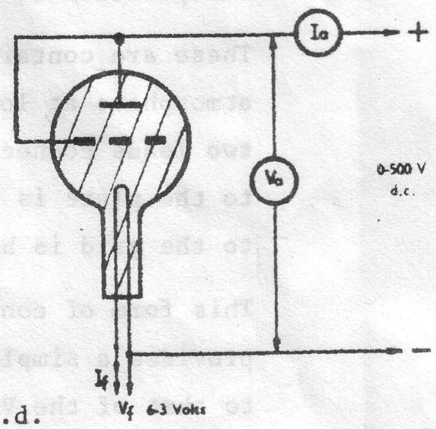


FIG.1

1.i When the filament is cold, no current flows between the plate and filament for a potential less than about 300V, but at some critical voltage, the 'striking' voltage, near this value, a small current of about 10uA flows.

1.ii A luminous discharge throughout the bulb is visible in a darkened room; intensity increases with p.d.

1.iii With the filament heated no current is detectable (c.c. Experiment 1 B (Series A) with no p.d. across the electrodes.

1.iv With a p.d. across the filament and plate the flow of current is small and gradually increases until about 20V when it increases very rapidly to exceed that of the vacuum diode at the same p.d.

1.v The current depends directly on the temperature of the filament for a given p.d. between the electrodes.

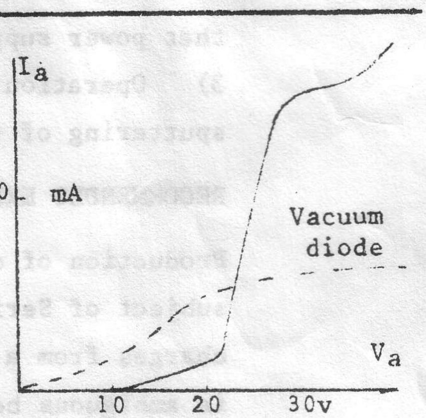
1.vi A luminous discharge is clearly visible between the electrodes with a p.d. of about 50V.

EXPERIMENT 2 (SERIES B) LOW CURRENT STUDY OF THE DIODE.

With the circuit in Figure 1 make a detailed study of the IA/VA curve over the voltage range 0-40V,

2.i Observe the sudden increase in current at about 20V.

2.ii Observe the 'structure' in the curve in the region 20-25V.



2.iii Inspect the region between the plate and filament with a spectroscope and note the appearance at about 25V of a line spectrum; superimposed on the continuum of the white light.

FIG.2

EXPERIMENT 3 (SERIES B) HIGH CURRENT EXAMINATION AND THE SEARCH FOR SATURATION.

With the circuit in Figure 1 investigate the I_a/V_a curve over the range 0 - 500V. Repeat the experiment with a 10K ohm 10 watt resistor as anode load, and observe.

3.i Without the anode load the current decreases after reaching a maximum at about 150V because of the 'regulation' of the power supply used. Fig.3 (a).

3.ii With the anode load the current continues to increase indefinitely and shows no tendency to reach saturation as in the vacuum diode, i.e.the current is not limited by space-charge. Fig.3 (b)

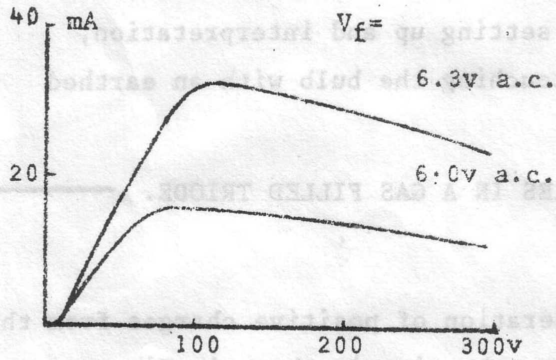


Figure 3 (a)

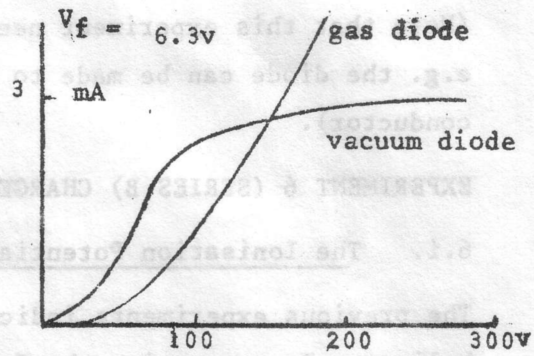


Figure 3 (b)

EXPERIMENT 4 (SERIES B) THE THERMIONIC EFFECT IN GAS (REVERSAL OF POLARITY).

In Experiment B1.i.flow of current is observed when V_a exceeds about 300V. Because of this, attempts to repeat with the Gas Triode the thermionic effect experiment in air fail, because the charge on a gold leaf electroscope exceeds this voltage.

Thus, unlike the vacuum diode, a current flows when the plate is made negative and continues to flow even when the filament is allowed to become cold. The gas diode cannot be used as a rectifier.

EXPERIMENT 5 (SERIES B) THE COLD CATHODE DISCHARGE.

With the circuit in Figure 1 with the filament cold, observe

5.i. The current increases with V_a after the 'striking' voltage has been attained.

5.ii. When the plate is negative, the striking voltage is not much influenced by whether the filament is cold or hot.

5.iii The spectrum of the luminous discharge is similar to that observed in Experiment 2.iii.

The striking voltage is dependent on the nature of the gas and its pressure. When the gas has become conductive, it is said to have 'ionised' (cf electrical conduction of ions in aqueous solutions of salts) both positive and negative charges having been liberated.

Observations indicate that a luminous discharge always accompanies ionisation of the gas.

EXPERIMENT 7 (SERIES B) ULTRA VIOLET EXCITATION OF A GASEOUS DISCHARGE.

With the circuit in Figure 1 and with the filament cold, adjust the p.d. across the electrodes to a few volts below the striking voltage. Observe the onset of ionisation when the bulb is irradiated by an U.V. source (5watt bacterial lamps are not adequate) or with X-rays. From this experiment it appears that the process is a reversible one, i.e. electromagnetic radiation of certain wavelengths will cause ionisation.

(Note that this experiment needs care in setting up and interpretation, e.g. the diode can be made to strike by touching the bulb with an earthed conductor).

EXPERIMENT 6 (SERIES B) CHARGE FLOW STUDIES IN A GAS FILLED TRIODE.

6.i. The Ionisation Potential.

The previous experiments indicate the liberation of positive charges from the helium. By connecting the Gas Triode into the circuit shown in Figure 4, the flow of any positive charge I_p will be indicated by the meter which is connected to the plate, since the latter is at negative potential and will attract a proportion of any positive charges liberated.

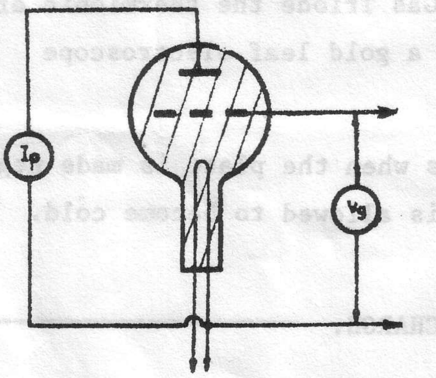


FIG.4

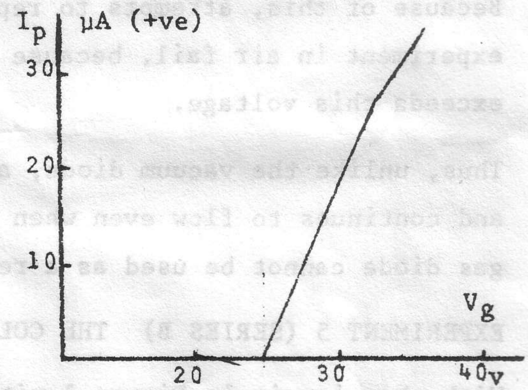


FIG.5

Observe

6.i.1 The flow of positive current commences at a 'critical' potential - the 'ionisation potential'.

6.i.2 The current increases with potential once ionisation has occurred.

6.i.3 The luminosity of the discharge increases with potential (see observation 1.vi).

6.i.4 The spectrum of the discharge comprises of lines the intensity but not the wavelength of which increases with voltage.

A Collision Theory.

The Gas Triode is of indentical structure to the Planar Triode; the filament when hot can be shown to emit electrons (Experiment 1). A luminous discharge is observed in the region of the electrodes once the gas has been ionised. It is reasonable to conclude that this can be due to collisions between gas atoms and electrons resulting both in the loss of electrons from atoms and in the emission of discrete wavelengths. The inference from these observations is that the collision processes are quantised.

If this is true, the stream of electrons can be expected to lose some of their kinetic energy in definite amounts. To test this, an experiment, originally due to Hertz, can be made.

6.ii <u>The Non-Elastic Collision of Electrons with Gas Atoms.</u>

Connect the Gas Triode into the circuit in Figure 6.

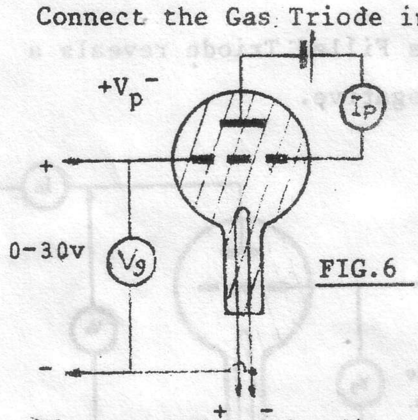


FIG.6

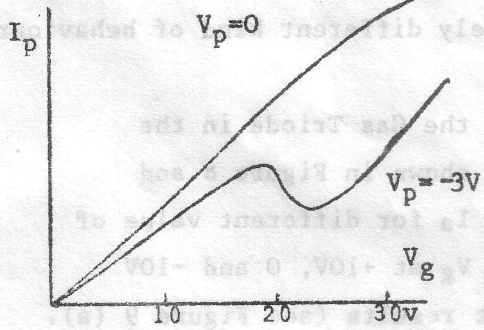


FIG.7.

Electrons from the filament are accelerated into the region between grid and cathode as before and will have a kinetic energy of Va electron volts. If a non-elastic collisi occurs, and a definite amount of energy is transferred to the atom, the electron will become less energetic. With the plate connected to the grid via a meter so that it is at the same potential, all electrons irrespective of energy losses will be collected and measured; (Fig.7, $V_p= 0$). By making the plate a few volts negative with respect to the grid (by inserting a battery up to 4.5V) electrons with only enough energy to overcome this potential drop will be measured and all others will be repelled; (Fig.7, $V_p= -3V$).

From this curve observe

6.ii.1 That non-elastic collisions do occur is confirmed.

6.ii.2 Such collisions apparently occur before ionisation at 25eV, commencing from about 20eV.

6.ii.3 The curve reveals no 'structure' corresponding to the discrete wavelengths; this is because the experiment is not sufficiently refined, i.e. in addition to the accelerating voltage, there is the 6V drop across the filament which results in an energy spread from V_g to V_g+V_f that is greater than range between onset of excitation, 20V and ionisation, 25V.

However, sufficient evidence is provided by this experiment to establish that non-elastic collisions occur at energies lower than those in which electrons are removed from the gas atoms to cause ionisation. The light emitted before ionisation occurs is of such wavelengths and intensity as not to be detectable with a simple spectroscope with this tube.

To obtain evidence of a series of energy levels corresponding to the discrete wavelengths in the emission spectrum, it is necessary to employ a source of electrons having a relatively narrow band of energies (e.g. the Critical Potentials Tube TEL 533)

EXPERIMENT 18.i (SERIES B) CHARACTERISTIC CURVES OF THE GAS FILLED TRIODE.

The characteristic curves of the vacuum triode give a graphical representation of its electrical properties. Experiment 20 (Series A) gives the relationship between I_a/V_a at constant V_g and I_a/V_g at constant V_a (Figure 7).

Investigation of the I_a/V_a characteristic of the Gas Filled Triode reveals a completely different kind of behaviour when V_g is negative.

Connect the Gas Triode in the circuit shown in Figure 8 and measure I_a for different value of V_a with V_g at +10V, 0 and -10V and plot results (see Figure 9 (a).

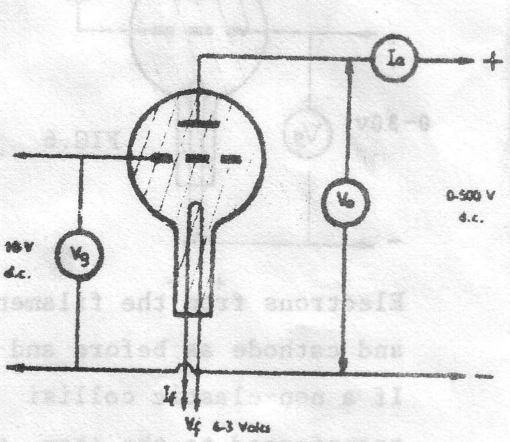


FIG.8

Observe that

18.1 with V_g positive, I_a increases rapidly after V_a exceeds about 20V (compare with Figs. 2 & 3)

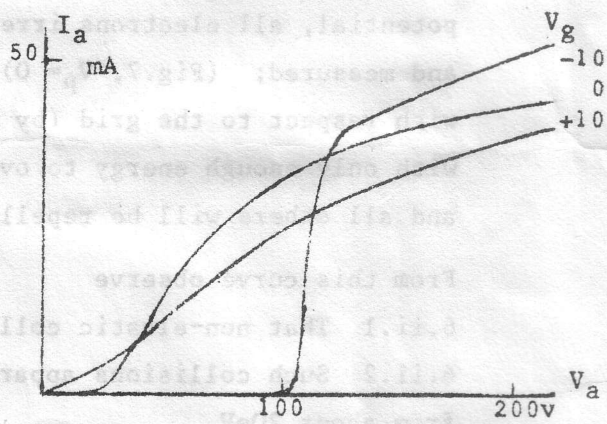


FIG.9 (a)

18.2 with V_g zero, no current flows until V_a is about 22V when a sharp increase occurs and then follows the form of the previous curve.

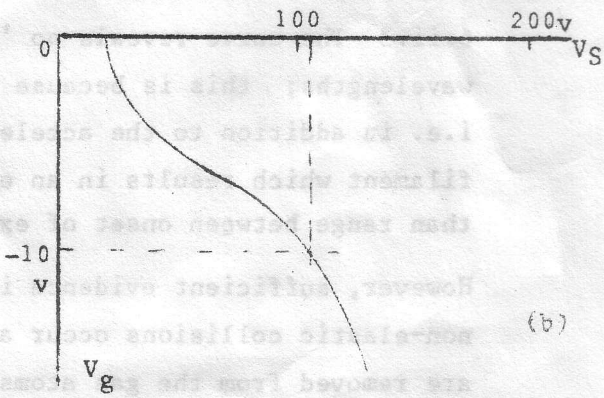


FIG.9 (b)

18.3 with V_g negative, no current flows until a 'striking' voltage V_S is reached when I_a increases very rapidly to exceed previous values. In this condition the Gas Triode is behaving as a switch; gas-filled valves designed specifically to function in this way are called "thyratrons" (there are solid-state counterparts called thyristors)

18.4 all the characteristics are dependent on the temperature of the filament.