Rutherford Laboratory

Technical leaflet

SPACE CHARGE HIGH VACUUM GAUGE

An example of the new type of high vacuum ionization gauge in which the ions are trapped in the space charge of a high current electron beam is exhibited, together with a transistorized control unit which displays the pressure on a meter with a linear scale.

The gauge (Figure 1), which operates in the pressure range 10^{-4} to below 10^{-8} torr, is not only simpler than the conventional ionization gauge, but also has a very rapid response time: for example it requires only about 10 μsec to measure a pressure of 10^{-5} torr. The device is a direct development from an academic study made at the Rutherford Laboratory on the effects of space charge in very high intensity electron beams.

The gauge operates as shown in Figure 3: when a pressure measurement is to be made switch S is closed causing a beam of electrons to be accelerated from the hot emitter into a "field-free" drift space. There the beam diverges strongly due to electrostatic repulsion between the electrons (Figure 3(a)). Each electron has a certain chance of colliding with one of the gas molecules in the drift space knocking an electron from it to form a positive ion. The ion is then trapped in the negative space charge of the beam; some of this charge is therefore compensated or 'neutralized', so that the force causing the electrons to spread sideways is decreased. This allows more of the beam to pass through the drift space to the target. As time goes on, more and more ions are formed and trapped, so that the target current steadily increases as shown in (b) and (c) of Figure 3. The rate at which the target current increases is directly proportional to the rate of ion production and is therefore directly proportional to the gas pressure, which can thus be measured. The numerical values in the diagram are typical of those at a pressure of 10^{-5} torr. This rate of current rise can be measured in the case of transient pressures by using an oscilloscope, or for steady pressures by pulsing the gauge frequently and using a simple transistor circuit (see Figure 2) the pressure being displayed on a meter. The latter makes use of an experimental fact that, initially, the target current rises exponentially.

The big advantage of this gauge results from the high efficiency of the ion trap, in which ions can be held for periods of up to a second. Thus each ion can neutralize the space charge of a whole succession of electrons in the beam, so that the gauge head itself acts as an amplifier of high gain, the currents involved being of order many milliamps. A sensitive external DC amplifier, which must be used with a conventional ionization gauge, is therefore not necessary.

THE GAUGE

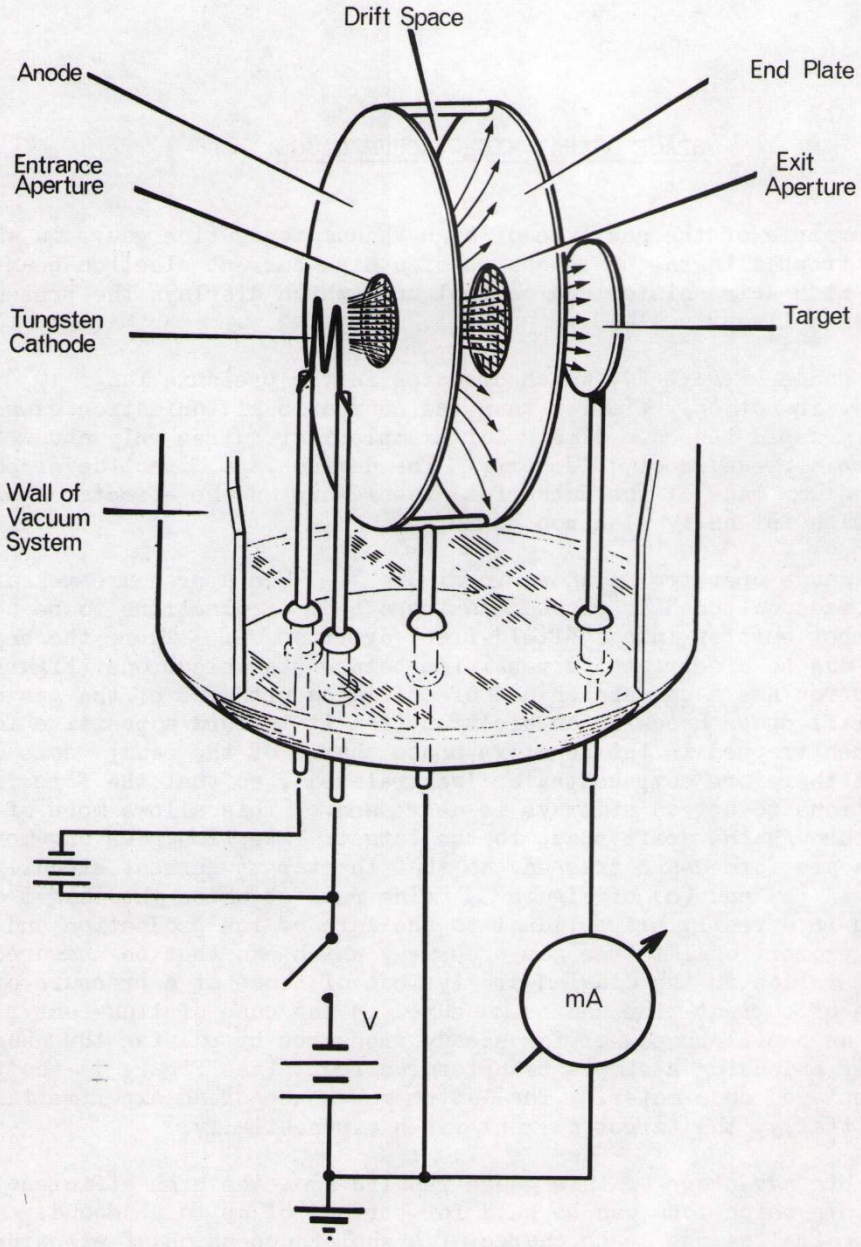

FIGURE 1

GAUGE CONTROL CIRCUIT

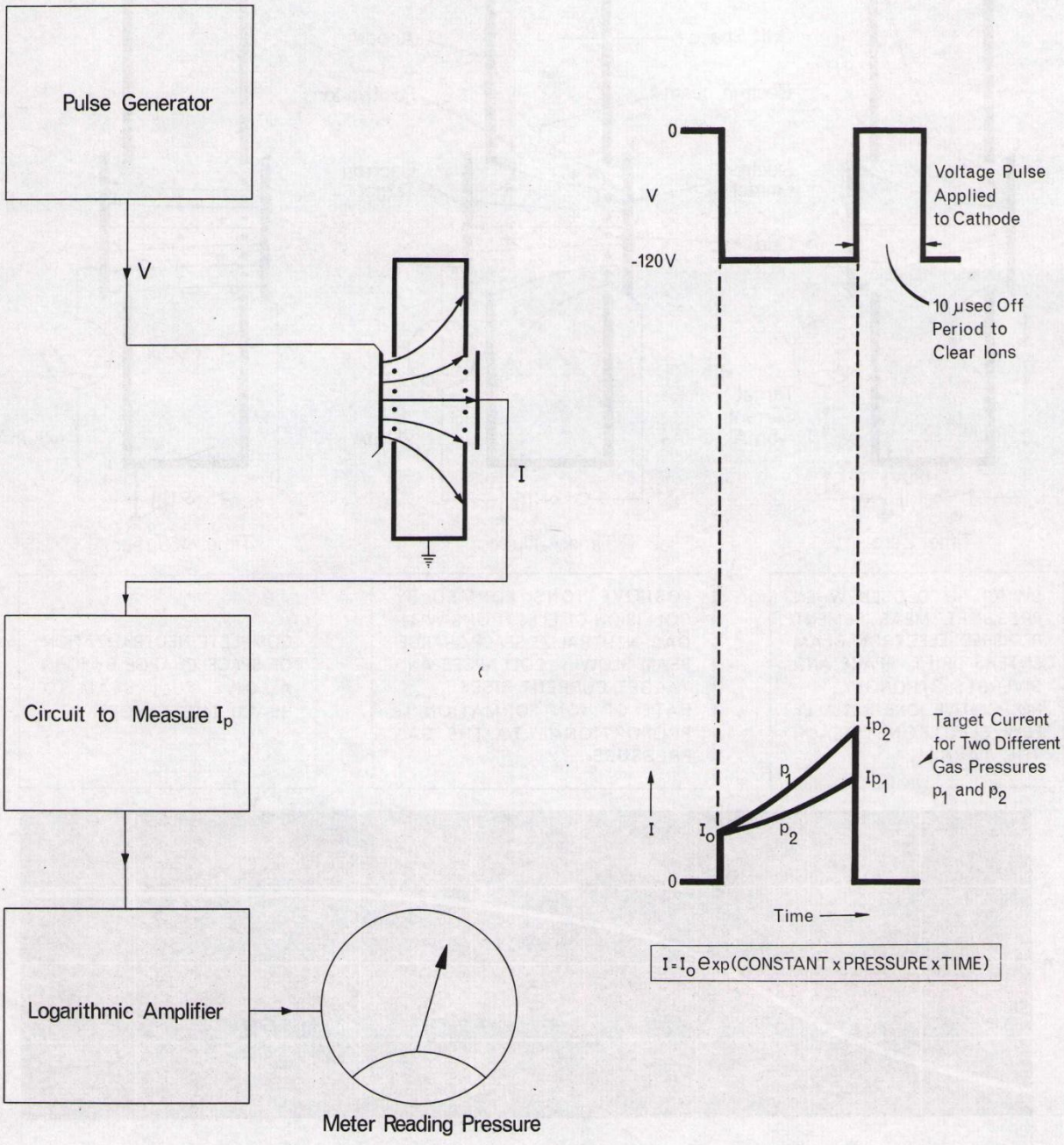

FIGURE 2

BASIC OPERATION
or how to measure 10^{-5} torr in 10μ sec.

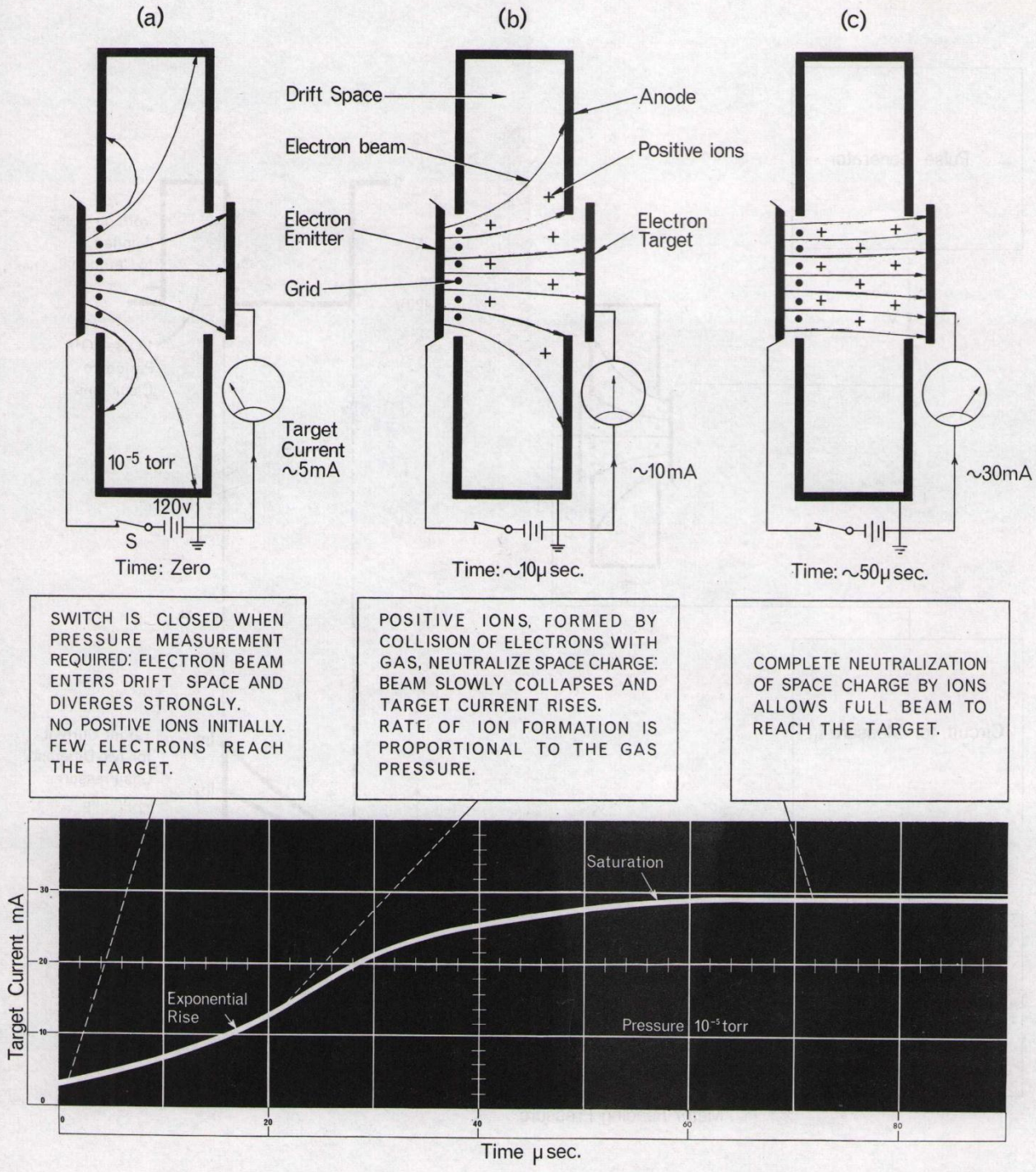

FIGURE 3