Rutherford Laboratory

Technical Leaflet

A19

A VACUUM GAUGE USING ION TRAPPING

An entirely new type of high vacuum ionisation gauge has been developed in which the ions are trapped in the space charge of a high current beam of electrons. The gauge is not only more simple than the conventional ionisation gauge, but also it has a very rapid response time: for example it requires only 10 microseconds to measure a pressure of 10^{-5} torr.

The device is a direct development from an academic study the group has been making of the effects of space charge in electron beams of very high intensity.

The gauge makes use of the well known fact that a repulsive force exists between electrical charges of the same sign. The hot filament in the gauge emitts electrons which are accelerated to about 100 volts and enter a small drift space as shown in the first figure. Here the electrons repel each other so strongly that the beam rapidly "blows up" sideways. However, each electron has a certain chance of colliding with one of the gas molecules in the vacuum system, knocking an electron from it to form a positive ion. The ion is then trapped in the drift space because it is attracted to the negative charge of the electrons of the beam; some of this charge is therefore compensated or 'neutralized', so that the force causing the electrons to spread sideways is decreased. At relatively high pressures of gas in the equipment, positive ions are formed very rapidly by these electron collisions, and so the beam spread decreases very rapidly: at low pressures, ions are formed very slowly and the electron beam takes much longer to become neutralized. Hence the rate of collapse of the beam is directly proportional to the pressure in the system, which can thereby be measured.

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 many seconds. 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. A sensitive external DC amplifier, which must be used with a conventional ionisation gauge, is therefore not necessary.

The new gauge and its basic control circuit is shown in figure I. The collapse rate can easily be measured in practice by observing, by means of an oscilloscope, the time rate of change of current to the target electrode as shown in figure 2. A direct reading on a meter can be obtained using a simple transistor control unit.

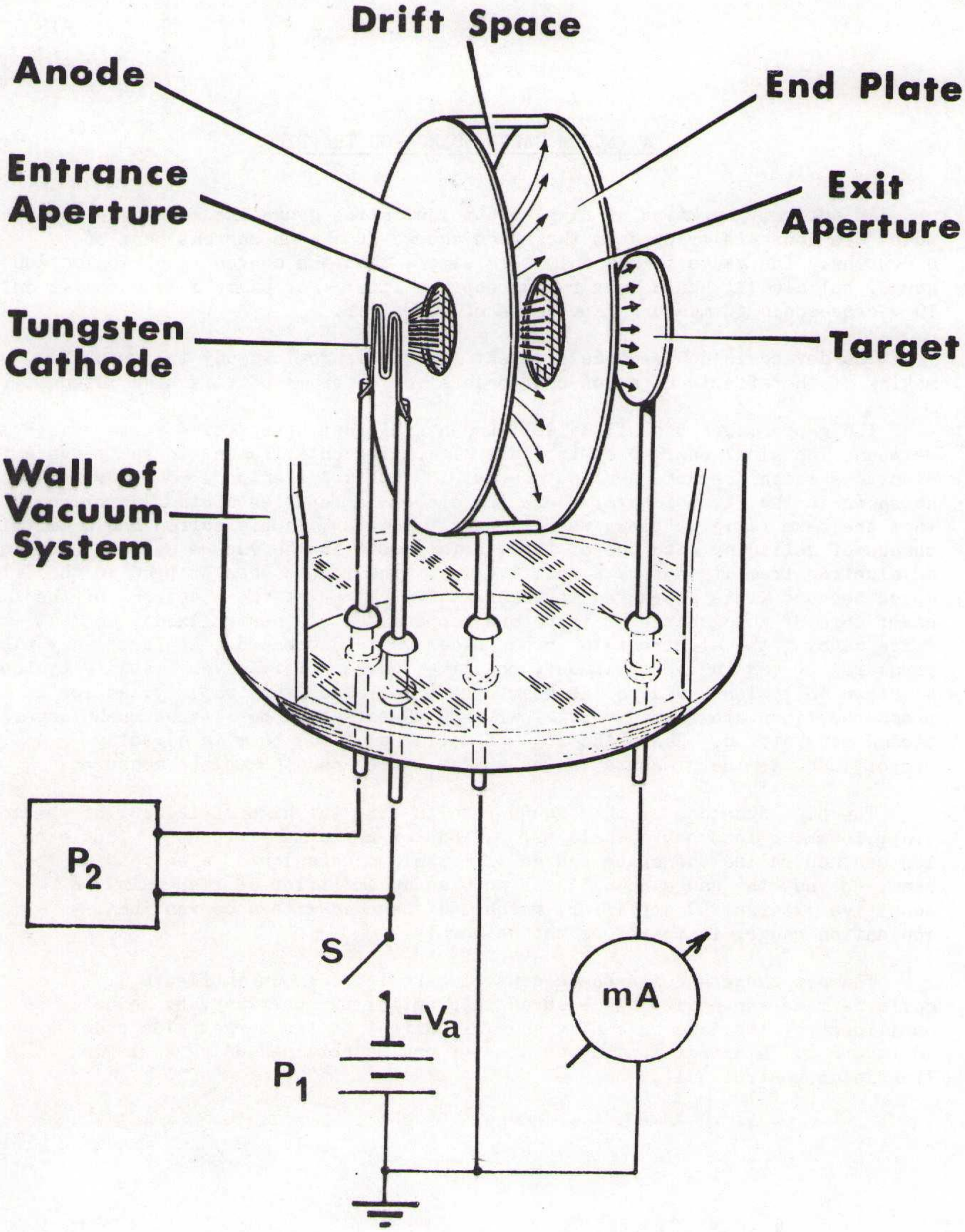
Drift Space
Anode
End Plate
Entrance Aperture
Exit Aperture
Tungsten Cathode
Target
Wall of Vacuum System
P_2
S
$-V_a$
P_1
mA

FIGURE 1

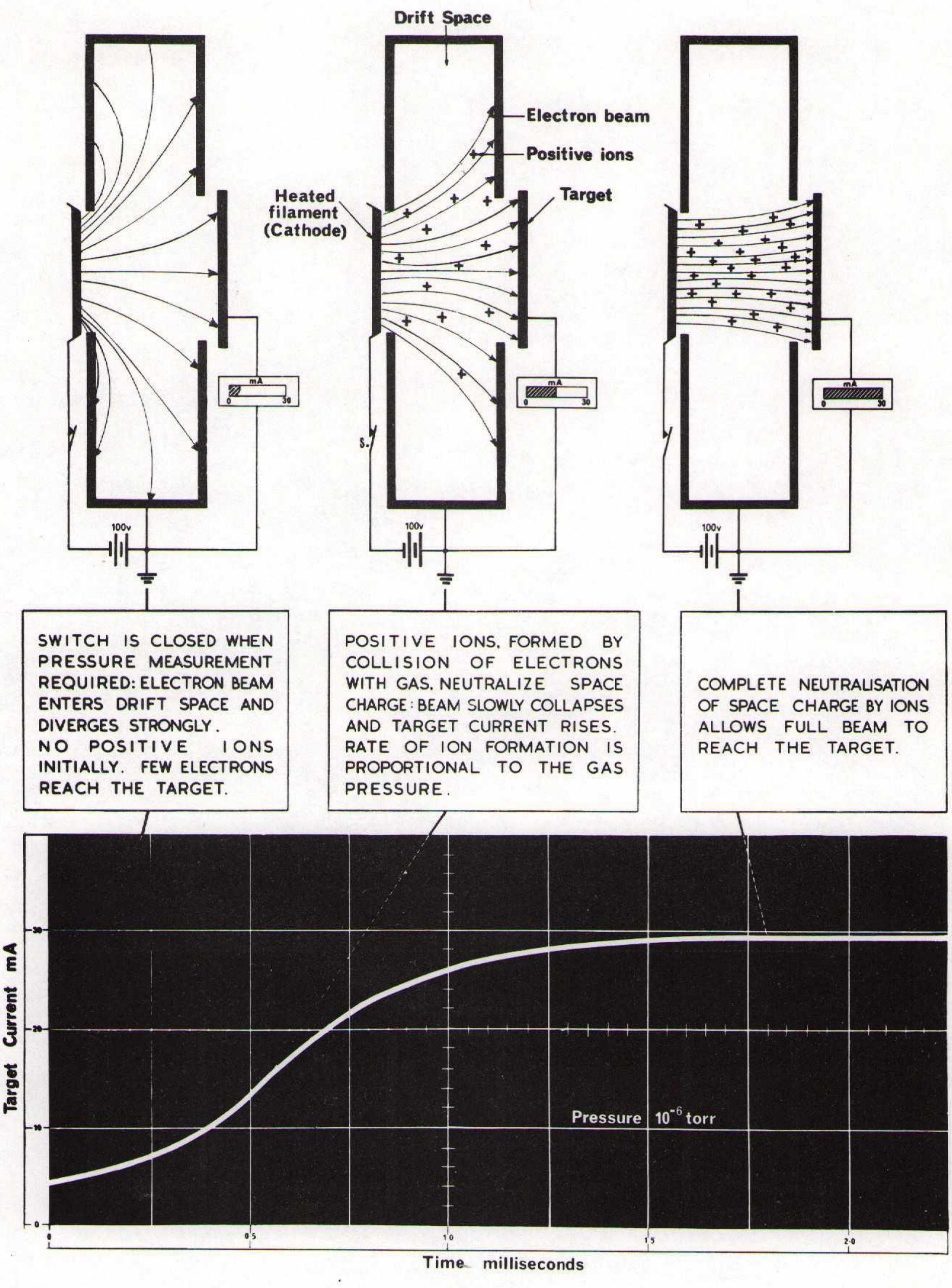
Drift Space
Electron beam
Positive ions
Heated filament (Cathode)
Target
mA
0
30
S.
100v
SWITCH IS CLOSED WHEN PRESSURE MEASUREMENT REQUIRED: ELECTRON BEAM ENTERS DRIFT SPACE AND DIVERGES STRONGLY. NO POSITIVE IONS INITIALLY. FEW ELECTRONS REACH THE TARGET.
POSITIVE IONS, FORMED BY COLLISION OF ELECTRONS WITH GAS, NEUTRALIZE SPACE CHARGE: BEAM SLOWLY COLLAPSES AND TARGET CURRENT RISES. RATE OF ION FORMATION IS PROPORTIONAL TO THE GAS PRESSURE.
COMPLETE NEUTRALISATION OF SPACE CHARGE BY IONS ALLOWS FULL BEAM TO REACH THE TARGET.
Target Current mA
Pressure 10⁻⁶ torr
Time milliseconds
0
0·5
1·0
1·5
2·0
10
20
30

FIGURE 2.