OMEGATRON MASS-SPECTROMETER TUBE

Mass-spectrometer tube with platinum electrodes and tungsten cathode to be used for gasanalysis. Used with comparatively simple equipment, with this tube masses 32 and 33 can be completely separated.

Its sensitivity is large enough to make measurements possible at partial pressures of 10^{-10} to 10^{-11} torr.

By using platinum electrodes, the measuring qualities of this tube stay excellent also after repeated use. When cold, the tungsten cathode is insensitive to air of room temperature and atmospheric pressure.

The risk of damage during transport from factory to user is too large when the filament has been operated in the factory. For that reason the tube cannot be tested in operation before leaving the factory. The user, therefore, should test the tube immediately on receipt.

OPERATING PRINCIPLE (see fig. 1)

Electrons emitted by the cathode are concentrated into a beam by a magnetic field and collimated by circular holes in the grids g_1 and g_2 and in the box D. The beam traverses box D, passes through a second hole in box D and is collected by the electron collector T.

While traversing box D, the electronbeam ionises gasmolecules. The magnetic field forces the ions thus formed into helical paths around the axis of the electron beam. Most of them will escape from the box along the electron beam or be neutralised on the wall of the box D.

There are, however, ions with a mass such that their angular velocity around the axis of the electron beam is in resonance with the frequency of the electric field which results from the radio frequency voltage between box D and electrode H.
These ions will spiral out of the electron beam so far that they will strike and be neutralised by the ion collector P and cause a current from ion collector P to earth, which is amplified and measured.

Note: By choosing a suitable d.c. current meter it should be avoided that the voltage difference between ion collector P and electrode D is becoming too high. Values of 100 mV often have no appreciable influence on measuring results, but 10 mV is a safe voltage under any circumstances.

The relation connecting the frequency of the electric field between electrodes D and H, the mass of the ions that will strike collector P and the magnetic induction in the gap of the magnet is:

$$f_r = 15.33 \times 10^6 \times \frac{B}{M}$$

where: f_r is the resonance frequency in Hz
B is the induction Wb/m^2
M is the ion mass in mass units.

Ions of different masses can be selected from the collision area by adjusting the frequency of the radio frequency voltage applied to electrode H; the resulting current is a measure of the rate of formation of ions having a particular mass.
Thus by progressively varying the frequency, a mass spectrum can be recorded.

The resolution of the omegatron is given by:

$$\frac{M}{\Delta M} = 6450 \times \frac{B^2}{V_{HD} M}$$

where B = magnetic induction in Wb/m^2
V_{HD} = R.M.S. value of the radio-frequency voltage between electrodes H and D in volts
M = ion mass in mass units

For $B = 0.4$ Wb/m^2, $V_{HD} = 1$ V and $M = 32$ the resolution $\frac{M}{\Delta M} = 32$

Thus a system equipped with a 0.4 Wb/m^2 magnet will allow complete separation over an interval of at least one mass unit of masses up to and including 33 mass units.

When no spurious effects are encountered, the curve which shows the values of current I_P plotted against the R.M.S. value of the R.F. frequency voltage V_{HD} (all other values constant) will be practically horizontal for values of V_{HD} between 1 V and 2 V_{RMS}.
The value attained by current I_P in the horizontal part of the curve has the following relation to the gas pressure and the electron current I_T:

$$I_P = c . p . I_T$$

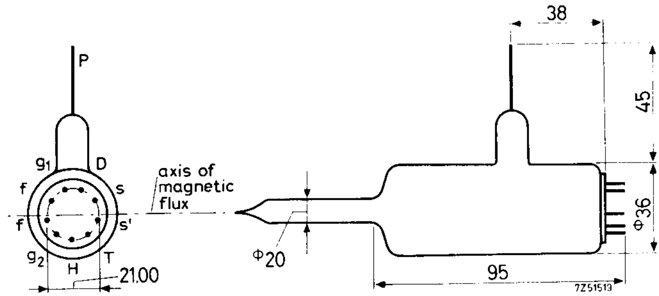
where p = partial pressure of the particular gas in torr.
I_T = current to electron collector T in amperes.
c = sensitivity constant depending on kind of gas and of mass number. An indication of the absolute value of this constant for the mass number with the highest peak of each gas is displayed on page 6 for 12 common gases. The relative values with regard to the highest peak are given there for other mass numbers for each gas.

The validity of the above relation, and hence also the method of measurement, is limited to pressures below 10^{-5} torr.

DIMENSIONS AND CONNECTIONS

Dimensions in mm

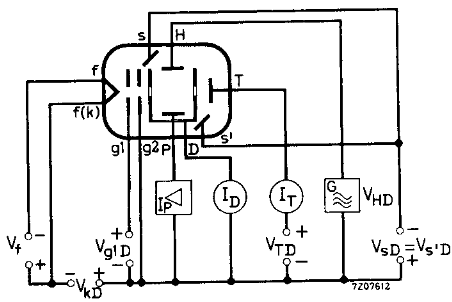
Base: Pin configuration according
to IEC-67-I-6a (B9G)



Envelope material: Fernico-sealing glass.

Note: When using a socket, all its magnetic parts should be removed.

RECOMMENDED CIRCUIT



V_f	0 to 2 V	V_{g2D}	0 V	V_{HD}	1 to 5 V_{RMS}
V_{kD}	- 90 V	V_{TD}	0 to 40 V	$V_{sD} = V_{s'D}$	0 to 60 V
V_{g_1D}	- 80 V				

Fig.1

ASSOCIATED EQUIPMENT

To operate the omegatron four major items of equipment will be required.

For most purposes satisfactory results will be obtained with equipment meeting the following specifications:

1. Permanent magnet: Pole distance 40 mm. Pole diameter 90 mm.
   Induction in the gap 0.45 Wb/m^2 (4500 gauss)

2. D.C. current meter, full scale deflection between 2×10^{-10} A and at least 10^{-13} A, preferably 2×10^{-14} A.
This measuring equipment should be designed so that during measurement the voltage difference between electrodes P and D will not exceed 10 mV. The meter should preferably have a response time below 2 seconds.

3. Radio frequency signal-generator:
Output voltage 1 to 5 V_{RMS}
Frequency range $60 \times 10^3 \times B < f < 16000 \times 10^3 \times B$ Hz
for the masses 1 to 250
B being the magnetic induction in Wb/m^2 in the gap of the magnet.

4. Power supply for the omegatron.

D.C. voltages required (fig. 1)

V_{kD}	= −90 V
V_{g1D}	= −80 V
V_f	variable from 0 to + 2 V
$V_{sD} = V_{s'D}$	variable from 0 to − 60 V
V_{TD}	variable from 0 to + 40 V

Note: The operation of the equipment is much simplified and often measurements are more exact if the power supply is equipped with a possibility for automatic regulation of V_{g1D} or I_f to keep the current to electron collector T constant at a required value. (I_f should never be allowed to become larger than 3.5 A corresponding to a V_f of approx. 2 V).

OPERATIONAL NOTES

1. Affix filament leads to filament pins and place the omegatron between the magnet poles.

2. Bring the pressure down to below 10^{-5} torr.

3. Connect all electrodes except P to their supply voltages as shown in fig. 1, adjust V_{TD} to 10 V, $V_{sD} = V_{s'D}$ to −10 V and adjust the filament current I_f so that a current I_D of 1 μA flows to box D.

4. Without changing the filament current I_f, the position of the omegatron in the magnetic field is so adjusted that current I_D attains a minimum value which should be below 10^{-8} A. Current I_T should now be 1 μA.

5. Connect the amplifier to the ion collector P.

6. Bring I_T on the value required by adjusting I_f. Usually, for measurements on gases with a partial pressure over 10^{-9} torr, a value of 1 μA will be chosen. For partial pressures below 10^{-9} the values for I_T will be progressively larger. At 10^{-11} torr a value of 30 μA will often be most convenient.

7. Tune the generator to the resonant frequency of a heavy mass, e.g. 28 and make V_{HD} 1.5 V_{RMS}
   By adjusting $V_{sD} = V_{s'D}$ and V_{TD} the ion current I_P is maximalized, I_T being kept on the same value. b
8. The optimum adjustment thus obtained for heavy masses has to be checked now for light masses. This more critical adjustment is carried out by tuning the generator to the resonant frequency of a light mass, e.g. mass 2, and again maximalizing the ion current I_P by adjusting $V_{sD} = V_{s'D}$ and V_{TD}. The deviation from the optimum ion current has to be made as small as possible for all masses (< 10%).
9. It is advisable not to exceed the following operating limits:

$$+5 < V_{TD} < +30 \text{ V}$$

$$0 < V_{sD} = V_{s'D} < -60 \text{ V}$$

$$I_f < 3.5 \text{ A}$$

BAKING

To clean the glass, baking temperatures up to 450 ^oC are allowed.
The platinum electrodes are not ordinarily subject to contamination, but if necessary they can under a pressure below 10^{-6} torr, be cleaned by heating up to 800 ^oC in a high frequency magnetic field.

WARNINGS

1. Operation of the tube at pressures above 10^{-2} torr will damage the filament.
2. Inhomogeneities in the radio frequency electric field between electrodes D and H may give rise to higher harmonics resulting in indications at mass numbers $\frac{M}{2}$, $\frac{M}{3}$, etc. There will be individual, but also day to day difference in the occurrence of these harmonics.

The higher harmonics are liable to interfere with the accuracy of the measurements. However, the spurious effect can easily be recognized and it can be eliminated at the cost of some sensitivity. Peaks whose height alter considerably when the value of V_{HD} is changed contain a higher harmonic component, and this can be removed by lowering that voltage or the gas pressure, or both. A further method ... which is also likely to reduce the sensitivity of the measurement ... is to add a negative bias of a few tenth of a volt to the radio-frequency voltage on electrode H. Conversely, it should be noted that liability to higher-harmonic interference is increased by raising V_{HD} and the gas pressure in the tube.

SOME MASS SPECTRA MEASURED WITH OMEGATRON

	1	2	4	12	13	14	15	16	17	18	19	20	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	43	44	c
H_2		100																															4.0
N_2						7.4	0.03										100	0.75															11
CO				3.3	0.04	0.55		1.3									100	0.88	0.2		0.02												11.8
CO_2				3.5	0.03	0.08		7.8									11.5	0.1			0.4											100	14
H_2O		1						1.8	21	100	14	0.23									0.13												10.5
He			100																														1.8
A												14.2													0.38		0.06		100				13
CH_4				1.8	5.7	12.5	81	100	2.7									3															7.4
C_2H_2		3.5		1.4	4.0	0.3							5.1	19	100	3.2																	15.5
C_2H_4				0.6	1.0	2.3	0.3	0.4					2.0	6.8	47	51.5	100	3.3															11.6
C_2H_6				0.2	0.55	2.0	3.1	0.15					0.5	2.7	18.1	27.6	100	20.5	25.9	0.54													14
C_3H_8				0.18	0.36	1.13	3.8	0.12					0.13	0.64	8.2	39.1	60.3	100	2.1						0.64	4.1	5.8	20		16	30.8	44.9	9

PHILIPS

Data handbook

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Electronic components and materials

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