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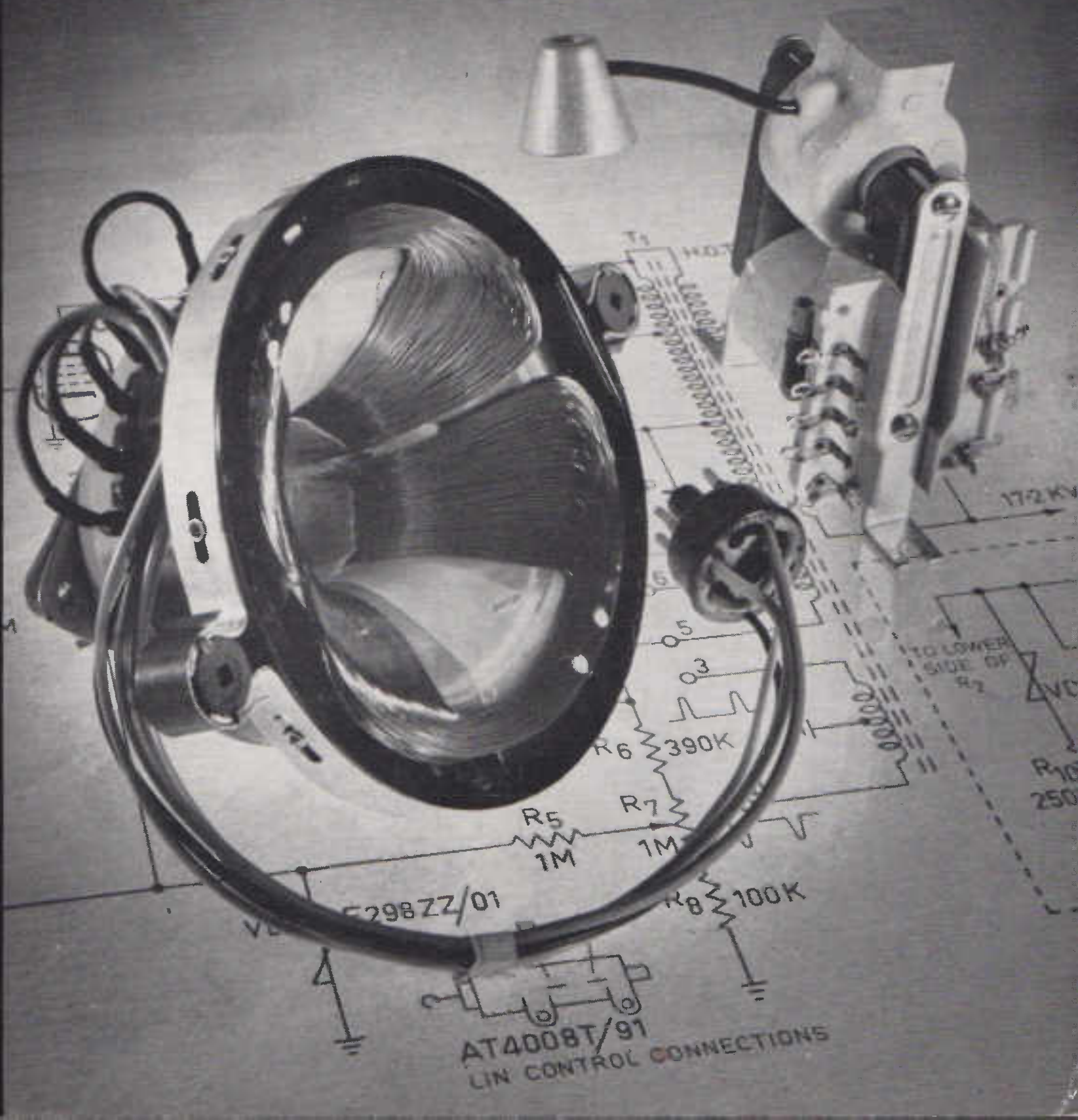
NEW DEFLECTION COMPONENTS FOR 17.2 KV EHT



NEW DEFLECTION COMPONENTS FOR 17.2 KV EHT

By increasing the final anode voltage of the picture tube, the quality of the television picture, particularly in its highlights, can be improved. For this reason, Miniwatt has recently released a new range of TV deflection components designed for operation at 17.2 KV EHT (previously 16 KV)—namely, the horizontal output transformer type NT3102 and the AT1011T series of deflection yokes. Simultaneously, the picture tube types AW59-90 and 23CRP4 have been uprated to 18 KV (previously 16 KV).

Why Higher EHT?

In Australia, the extension of viewing time mainly into the daylight hours has increased the requirement for adequate picture contrast under conditions of higher ambient light. This has led to the use of darker safety glasses in front of the picture tube screens proper, so as to absorb more of the reflected ambient light and thus maintain proper contrast. The increased absorption, however, also requires an increased light output from the picture tube. If an attempt is made to achieve this solely by raising the beam current, the result will generally be unsatisfactory, mainly due to the fact that an increased average beam current causes larger spot size (poor focus) and "blooming" of the highlights. These effects can be avoided by raising the EHT instead of the beam current. This method has the following advantages:

1. Higher picture brightness for given beam current.
2. Smaller spot size at given brightness level.
3. Reduced highlight blooming.
4. Improved overall picture quality.

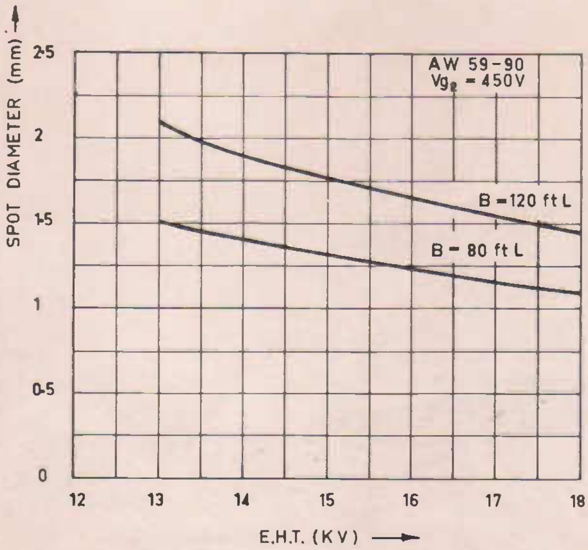


Fig. 1. Variation of spot size with EHT.

The relationship between spot size and EHT for two values of highlight brightness is shown in Fig. 1, where it can be seen that at constant brightness of 120 ft.—Lamberts, the spot size decreases by 7.6% when the EHT is raised from 16 to 17.2 KV. At maximum beam current the improvement is even more pronounced.

EHT Rating of Picture Tube

It is obvious that in order to make use of the benefits of increased EHT, the picture tube must be capable of withstanding the higher voltage applied to the final anode. Improved manufacturing techniques for the electron guns of Miniwatt AW59-90 and 23CRP4 picture tubes, applied for some time past, permit the raising of the maximum EHT rating from 16 KV to 18 KV (design-centre rating system). The increased rating applies to all stock of the above types at present held in Australia.

Deflection Yokes Series AT1011T

This new series of yokes succeeds the well-known series AT1009T which has been in use since the introduction of 110° deflection. The new series is designed for use with 23" and 19" 110°/114° picture tubes operating with EHT voltages up to 18 KV. In dimensions and construction it is almost identical to the series AT1009T, but it is *not to be used as a direct replacement* since its horizontal and vertical sensitivities and impedances are slightly different. New horizontal and vertical deflection circuits to match the new series yokes are described later in this article.

Since the deflection sensitivity of picture tubes is inversely proportional to the applied EHT, it follows that an increase in EHT from

16 KV to 18 KV would normally require approximately 13% more deflection energy. By careful design of the coils it was possible to partially compensate for the increased energy demand. The required deflection currents in both directions are only slightly higher for the AT1011T at 18 KV than for the AT1009T at 16 KV.

The shape and winding distribution of the coils have been chosen to produce a raster having minimum geometric distortion on the screens of the more rectangular 19" and 23" picture tubes. The "Pullback" range has been increased compared to that of the 1009T, which allows the manufacturer greater margin for tolerances with regard to yoke and picture tube assembly, stray field orientation, etc. The unit also offers several possibilities for fine adjustment of the raster shape. However, for the convenience of the user, it is supplied factory pre-set for optimum raster shape on an average picture tube type AW59-90. The following adjustment facilities are provided (see also Fig. 2):

1. Two Ferroxdure ferrite magnets mounted on sliding clips for compensation of horizontal "pincushion" distortion. These magnets are normally set in the rear position ready for use with AW59-90 tubes. For other tube types with more inherent pincushion distortion it may be necessary to slide the magnets closer towards the picture tube face.
2. Two cylindrical correcting magnets for compensation of vertical pincushion distortion. These are diagonally magnetised and can be turned between pole shoes for correct field distribution. Normally these magnets do not require field adjustment and are factory sealed.
3. Two centring magnets for centring the raster on the picture tube face. These are two diametrically magnetised steel annuli which can be rotated independently so that the resultant field can be varied in both strength and direction.

   This adjustment should be used only to compensate for the eccentricity of the picture tube and deflection yoke (for which it is intended) and not to counteract the effects of non-linear scan, excessive phase differences due to horizontal flywheel sync. or incorrect vertical retrace time. If incorrect use is attempted, the raster geometry will deteriorate.

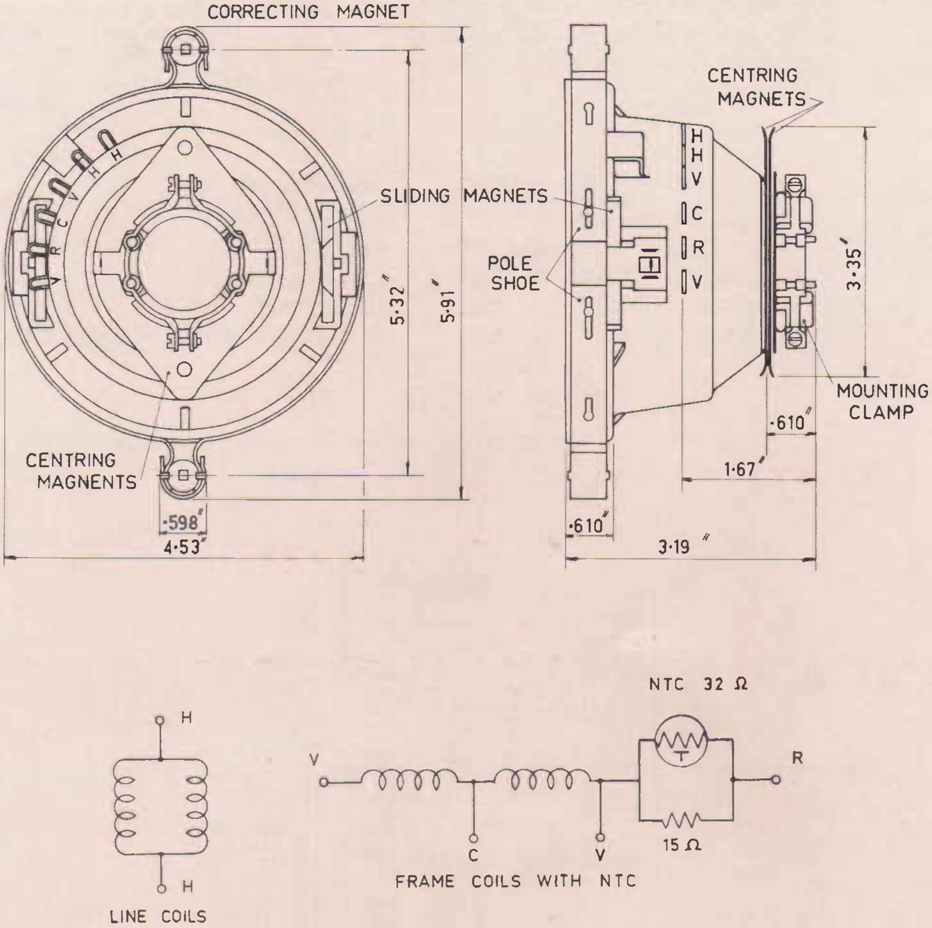


Fig. 2. Dimensional drawing and coil connections of deflection yoke series AT1011T. Type AT1011T/93 omits the NTC and resistor parallel combination.

A temperature-compensating network incorporating an NTC resistor is fitted in series with the vertical coils to maintain constant resistance throughout the temperature range 25°C to 85°C and thus maintain constant picture height. Yoke type AT1011T/93 is supplied without compensating network for vertical output circuits using current feedback.

The yoke assembly is secured to the tube neck by means of a resilient mounting clamp. A metal chassis should not approach the yoke closer than ⅜" at any point, and the clearance from the magnets and pole shoes should not be less than ¾". Larger clearances are preferable.

Three types of yokes in the AT1011T/ series are available — differing only in whether or not connecting leads and octal plug are fitted and whether an NTC network is included. Details are given below.

	Lead and Plug Assembly	NTC Network
AT1011T/93	Yes	No
AT1011T/94	No	Yes
AT1011T/95	Yes	Yes

Technical Data

	Horizontal coils	*Vertical coils*
Construction	Two saddle coils in parallel	Two toroidal coils in series
Resistance (Ω)	4.6	37 (47 with NTC)
Inductance (mH)	2.9	82
Deflection current (A_{p-p})	2.45	0.48
Deflection amplitude* (% picture overscan)	10%	3%

* *With tube AW59-90 at 17.2 KV EHT.*

Horizontal Output Transformer Type NT3102

This transformer has been designed for use in combination with the deflection yoke series AT1011T as described above. Its nominal EHT at zero beam current is 17.2 KV and it is therefore not a direct replacement for earlier types of transformers. It is intended for operation with the linearity coil type AT4008T/91 and valve types 6CM5, 6AL3 and 1S2, and it may be operated either stabilised or non-stabilised.

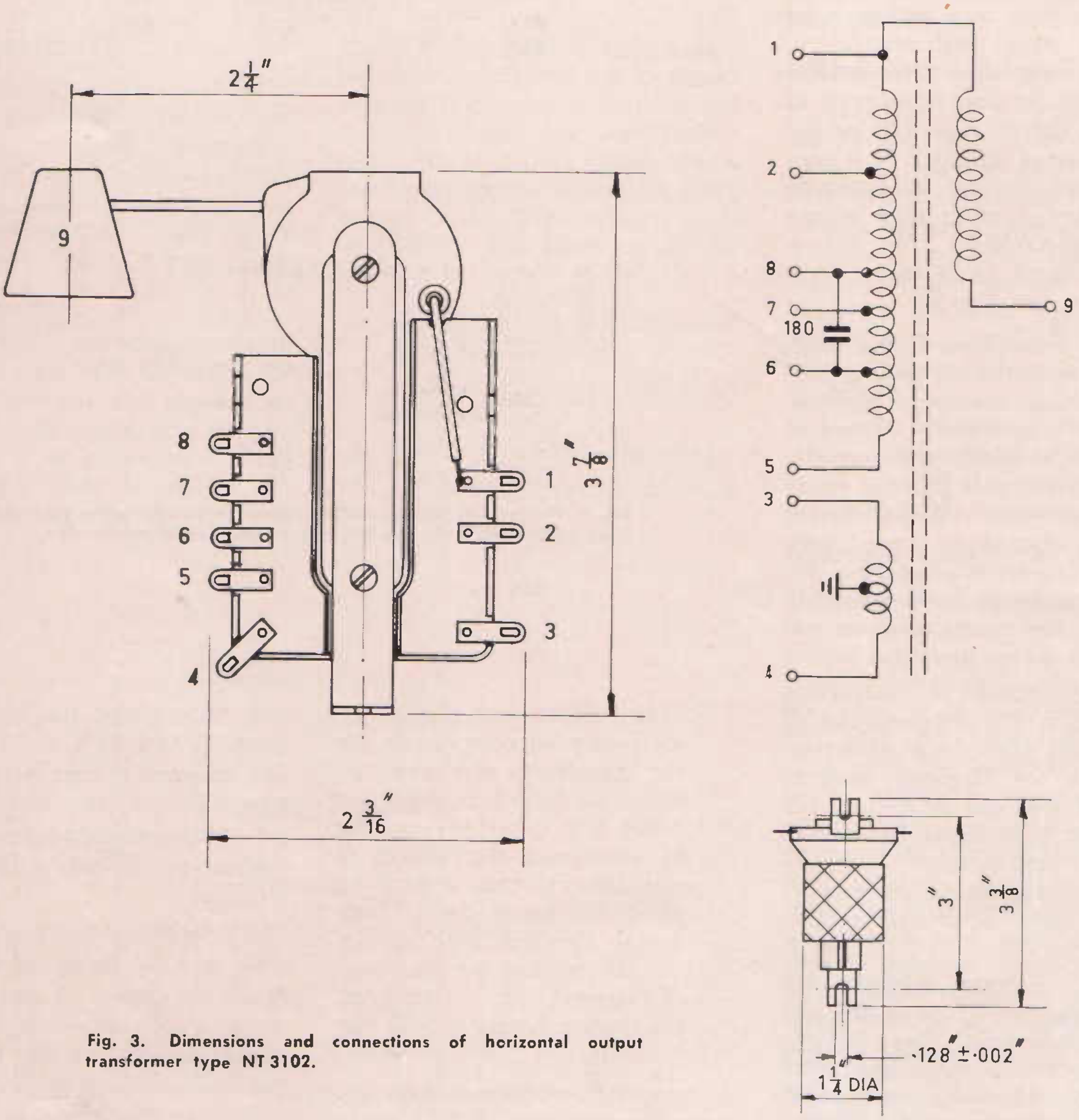


Fig. 3. Dimensions and connections of horizontal output transformer type NT 3102.

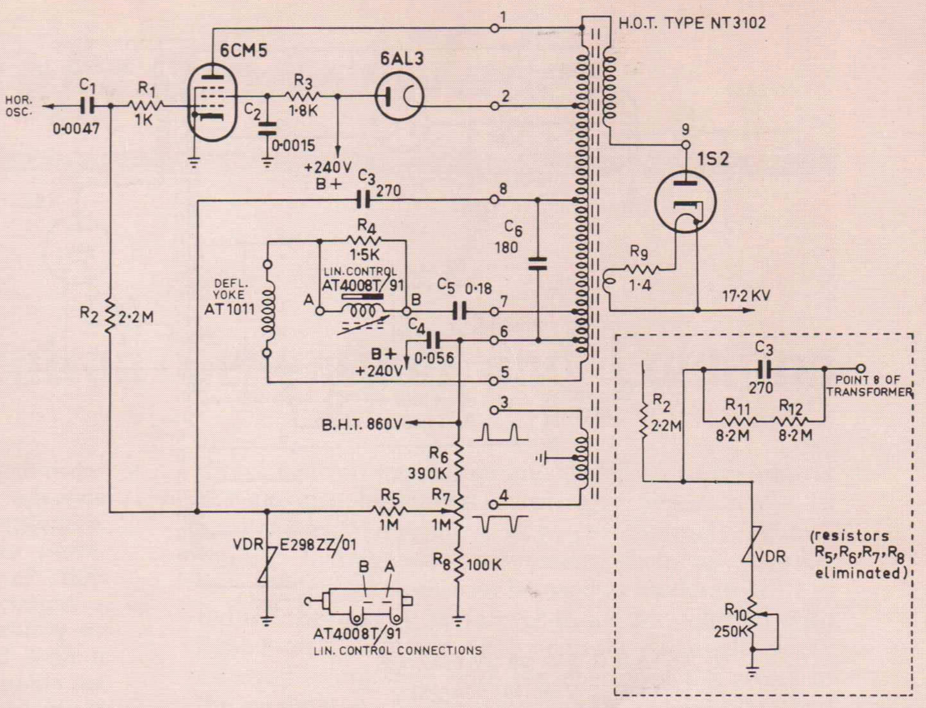
Mechanically, the unit embodies some new features which increase the safety factor of the transformer. The primary coil is now polyester dipped and the connecting lug panel is made of glass-reinforced polyester. The polyester-encapsulated EHT coil construction has been continued from earlier transformer types. The unit employs shorter U-cores made of an improved grade of ferrite (Ferroxcube ferrite 3C5).

The construction of the coils is such that the EHT coil leakage inductance and stray capacitances inherently provide correct third-harmonic tuning; hence the shorted turns used for this purpose on previous transformers could be omitted.

A tertiary winding with centre-tap connected to the rear transformer leg (grounded) is included to provide positive and negative flyback pulses of approximately 290 V peak amplitude for blanking and AFC purposes. To prevent disturbances of transformer tuning, excessive external capacitive loads must be avoided. The maximum external capacity across the whole tertiary winding (connecting points 3 and 4) is 100 pF and the maximum additional capacity across the yoke tappings (points 5 and 7) is 80 pF. Dimensions and connections of the transformer are shown in Fig. 3.

Notes on Mounting the Horizontal Output Stage

The distance between the EHT coil and any flat metal part should be at least 1". This also applies to the anode cap of the 1S2 and its connecting lead. The maximum permissible temperature of the transformer core and coils is 100°C. For this reason, the transformer should be positioned so that it is adequately cooled by the convection of cool air, i.e., the EHT cage should be placed towards the bottom of the set. The transformer and EHT rectifier socket should also not be subjected to excessive heat radiation from 6CM5 and 6AL3 valves. Some protection should be provided for the 1S2 heater cable against the heat of the transformer core, e.g., a silicon rubber sleeve.



R_1	1 K Ω, ½ W (B8 305 05A/1K)
R_2	2.2 M Ω, 1 W (B8 305 06A/2M2)
R_3	1.8 K Ω, 5 W, ww
R_4	1.5 K Ω, 1 W (B8 305 07A/1K5)
R_5	1 M Ω, 1 W (B8 305 07A/1M)
R_6	390 K Ω, ½ W (B8 305 06A/390K)
R_7	1 M Ω lin. pot, pre-set (E097AA/1M)
R_8	100 K Ω, ½ W (B8 305 06A/100K)
R_9	1.4 Ω, ½ W
R_{10}	250 K Ω lin. pot, pre-set (E097AA/250K)
$R_{11, 12}$	8.2 M Ω, ½ W (B8 305 06A/8M2)
VDR	Philips type E298ZZ/01

All wattage ratings at 70°C; required tolerances ± 10%

C_1	.0047 μF, 400 V, polyester (C296AC/A4K7)
C_2	.0015 μF, ceramic "pin-up" (C322BA/H1K5)
C_3	270 pF, 2.5 KV ceramic —
C_4	.056 μF, 1 KV paper —
C_5*	.18 μF, 125 V polyester (C296AA/A180K)
C_6†	180 pF, 700V ceramic (C321AA/A180E)

* For reduced overscan $C_5 = 0.20$ μF.
† Part of transformer assembly.

Fig. 4. Circuit diagram of stabilised horizontal output stage. Alternative stabilising circuit shown in insert.

Stabilised Horizontal Deflection Circuit

Fig. 4 shows the diagram of an output stage with a stabilisation circuit⁽¹⁾ resulting in substantially constant EHT and picture width despite variations in supply voltage and beam current, and despite valve ageing. The circuit is designed for a nominal HT supply voltage of 240 V; stabilising action will then be effective for supply voltages down to approximately 205 V. A somewhat simpler alterna-

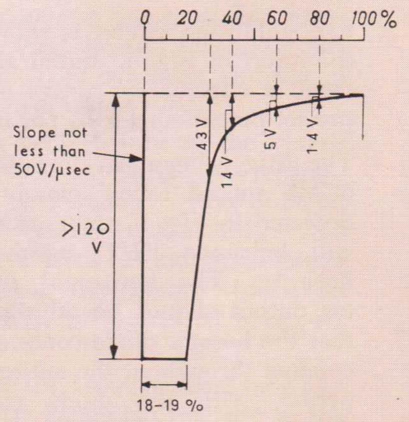
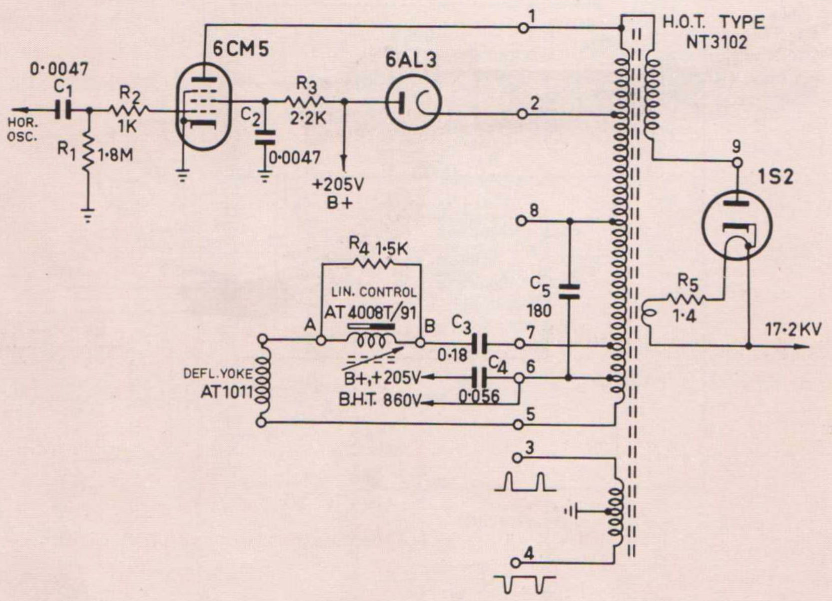


Fig. 5. Required drive for the stabilised output circuit.



R_1	1.8 M Ω, ½ W	(B8 305 05A/1M8)
R_2	1 K Ω, ½ W	(B8 305 05A/1K)
R_3	2.2 K Ω, 5 W, ww	—
R_4	1.5 K Ω, 1 W	(B8 305 07A/1K5)
R_5	1.4 Ω, ½ W	—

All wattage ratings at 70°C; required tolerance ± 10%

C_1	.0047 μF, 400 V polyester	(C296AC/A4K7)
C_2	.0047 μF, ceramic "pin-up"	(C322BA/H4K7)
C_3*	.18 μF, 125 V polyester	(C296AA/A180K)
C_4	.056 μF, 1 KV paper	—
C_5†	180 pF, 700 V ceramic	(C321AA/A180E)

* For reduced overscan C_3 = .20μF
† Part of transformer assembly

Fig. 6. Circuit diagram of non-stabilised horizontal output stage.

tive stabilising circuit is shown in the insert of Fig. 4. Initial adjustment is effected by means of the pre-set potentiometer R_7 (or R_{10}).

The drive voltage waveform for the 6CM5 should follow closely that depicted in Fig. 5, since its shape will influence EHT, width and linearity. The horizontal oscillator output should be adjusted so that the booster diode continues to conduct throughout the entire scan period, with the diode current dropping to 5 to 10 mA at the end of scan (at zero beam current). R_7 (or R_{10}) should be set (at zero beam current and nominal HT supply voltage) to give a boost addition voltage of 620 V, that is, a total boost voltage of 860 V.

If all the above requirements are met, width and EHT will automatically be correct within narrow tolerances.

Typical electrical measurement data of the circuit of Fig. 4 are tabulated below:

Beam current	0	400	μA
Flyback time	18	18	%
EHT	17.2	15.6	KV
Boosted HT	860	840	V

6CM5

Average cathode current	118	150	mA
Average screen current	19	20	mA
Average plate current	99	130	mA
Peak cathode current	287	360	mA
Peak plate current	252	324	mA
Screen dissipation	—	3.8	W

6AL3

Average current	100	132	mA
Peak current	225	230	mA

Non-Stabilised Horizontal Deflection Circuit

A circuit for non-stabilised operation is shown in Fig. 6. It is similar to that in Fig. 4 except that the stabilising circuit has been omitted and that the HT supply voltage must now be 205 V. Drive, boost addition and EHT voltages are also similar to the previous circuit.

Vertical Deflection Circuit for the AT1011T Series Yokes

As mentioned previously, the vertical deflection current of the new yoke is only slightly higher than that of the former yoke series AT1009T. The required increase is approximately 30 mA_{p-p}. In most cases it will therefore be possible to use the same vertical output circuit as with the AT1009T, provided that type 6GV8 output valves are used. Where the circuit incorporates a type 6BM8 valve, the operating conditions must be checked to ensure that the minimum plate voltage rating is adhered to and maximum plate current is not exceeded.

A suitable output circuit using the 6GV8 has been published in an earlier issue of the *Digest*(2) and the only recommended circuit change is to reduce the value of the pentode cathode resistor R_{17} from 470 Ω to 390 Ω.

References:

1. Boekhorst, A. and Stolk, J., Television Deflection Systems, Ch. 9, p. 147, Philips Technical Library, 1962.
2. Heins, P., The 6GV8—New Triode Pentode for Vertical Deflection, *Miniwatt Digest*, Vol. 1, No. 1, p. 8.

Professional Tubes

PHILIPS TUBES FOR

Neutron Generation and Counting

The advent of the sealed-off neutron generator type 18600 represents a revolutionary advance in the art of realising compact monoenergetic neutron sources. Its advantages include portability, a long life expectation (in excess of 1000 hours)—no longer limited by that of the target—and negligible fall-off in operating reliability or neutron yield throughout life. Supplied with a target EHT of 125 KV, this tube is capable of generating neutrons with an energy of 14 Me V at rates exceeding 10^8n/sec. (using the D-T reaction). Capable of pulsed operation (with shortest pulse duration = 5μS), the yield can be increased to 10^9 n/sec.

Following a treatment of the 18600 is a description of the current Philips range of tubes for slow (thermal) neutron detection. This comprises types ZP1000, ZP1001, ZP1010 and ZP1020, which between them cover a total flux range of 10^{-4} to 10^5 n/cm^2/sec., with good discrimination against gamma radiation.

Applications are discussed in the light of recent advances in neutron physics and neutron technology.

THE GROWING IMPORTANCE OF NEUTRONS IN SCIENCE AND INDUSTRY AND THE ADVENT OF THE 18600

Nuclear fission and nuclear fusion are both inherently concerned with neutrons, and it is in the controlled application of such phenomena that many of the present-day and future advances lie. The neutrons from controlled fission reactors are being used to produce radioactive isotopes for science, medicine and industry. However, their massiveness—and at times their remoteness—often mitigates against the study or practical application of reactor-produced radioisotopes. For example, due to the time consumed in transportation of the irradiated sample, it may only be possible to examine those elements having isotopes with greater than say 10 hours half-life. This could severely restrict an analysis.

Besides applications involving the use of α, β or γ radiation from artificially produced radioisotopes, direct neutron irradiation and detection techniques *at the site* are becoming increasingly important(1). In applications requiring a slow (or thermal) neutron source, hydrogenous substances such as paraffin, polyethylene or water can be used as moderators(18) to reduce the energy of fast neutrons by collision with light hydrogen atoms. The neutrons eventually reach an equilibrium state with the energy of the atoms of the moderator. As the water content of building and highway foundations, etc., is of prime importance, and as water is a natural neutron moderator, the potential of neutron analysis techniques for such applications is obvious.

Another useful technique is neutron radiography(2) which is complementary to X-ray or γ-ray radiography in that it reveals additional structural details because for any material the "relative absorption" of neutrons is different from that of γ or X-rays.

In considering peaceful uses of nuclear fusion we have the possibility of plasma(3)(4) power stations utilising fusion reactors in which light nuclei such as deutrons or tritons (nuclides of hydrogen) will have to be fused together at temperatures of the order of 10^8 °K, neutrons being emitted in the process. If ever practically realised, such a reaction would be a particularly rich source of fast neutrons. *It is in the optimum mechanisation of a nuclear reaction involving precisely such light nuclei, that Philips have answered the demand for a simple compact transportable high-yield neutron gun having long life and generating fast monochromatic neutrons. This has been realised in the form of a self-contained sealed tube.*

The development of this neutron tube in the Philips Research Laboratories(5) can be regarded as a resumption of the work of F. M. Penning(6) who built an experimental neutron tube as far back as 1937. This was a natural development from his ionisation gauge work. The importance of the Philips Ionisation Gauge (P.I.G.) has already been stressed in a previous article(3).

The practical utilisation of the 18600 neutron tube and the Philips neutron counter range is discussed in the final section of this article. For a more detailed description of the 18600, the reader is referred to Reifenschweiler and Nienhuis(7).

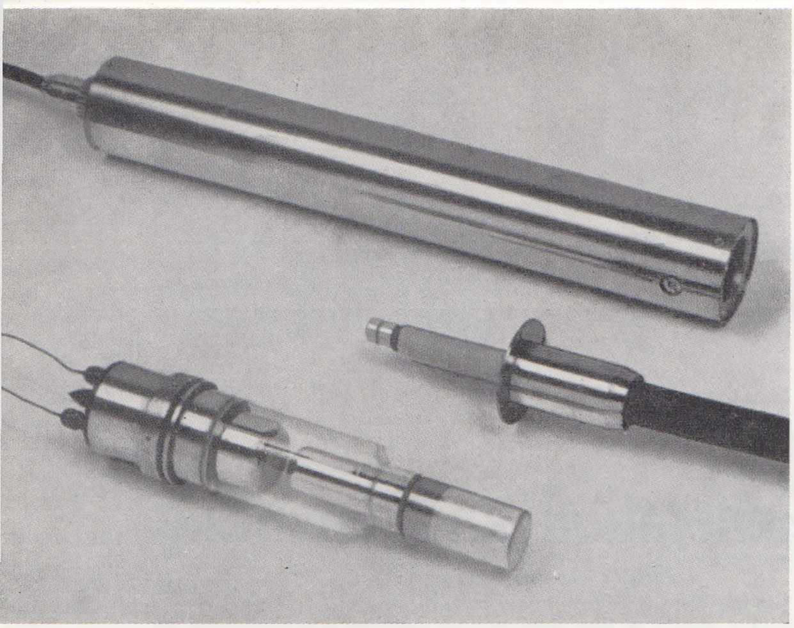


Fig. 1. The Philips neutron tube (at bottom in photo). The left-hand end of the tube, containing the ion source and a hydrogen pressure regulator, is at earth potential. High tension is applied to the right-hand end, via an HT cable and plug (centre). The tube as delivered (top) is enclosed in a metal cylinder with an outer diameter of 7 cm. This cylindrical sheath, which is earthed, affords mechanical protection and holds the HT insulation in place around the tube; it does not present ~~any~~ appreciable obstacle to the neutrons issuing from the target. These are expelled in all directions, but normal practice is to use only those with directions perpendicular to the tube axis.

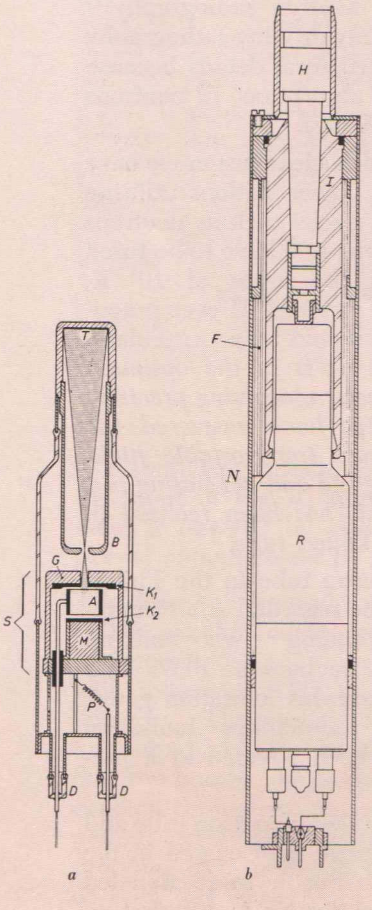


Fig. 2. (a) Constructional details of the Philips neutron tube. S Penning ion source, at earth potential, also acting as one electrode of the accelerating stage. B high-tension electrode, to which an accelerating voltage of 125 kV is applied. D feed-through insulators for supply voltages to ion source (2 to 3 kV) and hydrogen pressure regulator P (0 to 2 V). G soft iron walls of ion source chamber. M permanent magnet. K_1, K_2 are the disc cathodes and A the cylindrical anode of the Penning ion source. T target. The ion beam is shaded; its shape is determined by the properties of the electron-optical lens formed by G and B.

(b) Section through the neutron tube R enclosed in its earthed metal sheath N. I Araldite insulator. F oil-impregnated insulating foil. H plug of HT cable.

SUMMARY OF NEUTRON SOURCES

Since, in general, neutrons exist only as component parts of atomic nuclei, they can only be freed by way of nuclear reactions: a beam of fast lightweight nuclei (protons, deutrons or alpha-particles) can be used for this purpose. The energy of the incident particle plus the energy liberated by the reaction is shared between the product nucleus and the neutrons liberated. The individual energy acquired by the neutrons depends on their direction of emission relative to the incident particle, but monoenergetic neutrons can be obtained by collimation.

(a) From Radioactive Substances emitting Alpha-Particles

Such a neutron-producing reaction can be initiated by bringing radium or polonium (alpha producers) into contact with beryllium, for example. Although such a source is small and basically simple, and the rate of neutron emission is virtually constant, the neutrons produced have a complex energy spectrum which is often undesirable. Furthermore, with certain of these reactions the undesired gamma background is quite considerable. In addition, the neutron flux can neither be varied nor reduced to zero, and it obviously cannot be pulsed. Should the desired neutron yield exceed about 10^7 neutrons/sec. such a source will be uneconomic in addition.

(b) From Fission Reactors

A small portion of the neutrons produced in a reactor can be extracted via a duct in the reactor shield. For many applications requiring a high neutron flux, no better source can be found, but the use of reactor-produced neutrons is limited for the reasons given in the introduction.

(c) From Future Fusion Reactors

As mentioned in the introduction, neutron generation by such means has no practical significance at the present time, although it has future potential. Here the thermal energy of plasma(3)(4) at extremely high temperatures would be used to induce nuclear fusion.

(d) From Photo-Nuclear Reactions

Such reactions are produced when nuclei are exposed to high-energy gamma radiation. However, the gamma rays have themselves to be derived from radioactive substances as in (a), or produced in a large particle accelerator similar to those described in (e), with the attendant drawbacks specified in each case.

(e) From Bombardment of Light Nuclei with Artificially-Produced Particles

The possible nuclear reactions involved in such a process include the D-D and D-T reactions, that is, using bombardment of a deuterium, or respectively a tritium, target with high velocity deutrons (nuclei of deuterium). These reactions can be more fully expressed as D(d, n) He^3 and T(d, n) He^4, respectively.

That is, deutrons (d) bombard, respectively, a deuterium (D) or tritium (T) target to produce neutrons (n) together with helium product nuclei of respectively mass 3 (He^3), or mass 4 (He^4).

From the D-T reaction, which is the best high-energy neutron producer for bombarding energies less than 1 MeV, monoenergetic neutrons of 17.6 MeV can be obtained.

As the bombarding deutrons do not exist naturally, they must be produced in an ion source and artificially accelerated to a high velocity. Particle accelerators are used for this purpose, but although free of the drawbacks inherent in the neutron generators described in (a) above, they are generally very large and expensive.

In recent years there have been various attempts to build compact and, if possible, transportable versions of these accelerator-type neutron generators using the D-T reaction.

In the production of the 18600, Philips have overcome major limitations imposed by accelerators, basically in regard to cost, size and transportability. The same D-T reaction has been utilised, but in the optimum mechanisation of such a reaction within a sealed tube (with its inbuilt ion source and gas replenishing system) major problems had to be overcome. These will be described in the following section.

PROBLEMS WHICH HAD TO BE OVERCOME IN THE DEVELOPMENT OF THE 18600

—or criteria for optimum design of a sealed neutron generator.

If a major advance were to be achieved in producing a simple monoenergetic neutron source which is compact and transportable, the first objective should be to eliminate the need for the cumbersome and costly ancillary gas storage, supply and evacuating systems required by particle accelerators. The next problem would be to develop that construction which would provide a life expectation of at least 1000 hours, with the best yield possible. Both these requirements have been met by the 18600 which is depicted in Figs. 1 and 2.

In constructing a sealed-tube neutron generator, Philips have produced a compact transportable unit, but in freeing the device of bulky excrescences such as external gas supply and pumping system (which maintain the pressure differential required between conventional ion sources and accelerating systems) major problems had to be overcome.

In the first place, an ion source had to be found which would operate satisfactorily at a comparatively low gas pressure (to suit the requirements of the accelerating system), and then an accelerating system had to be designed which could operate at a comparatively high gas pressure (to suit the ion source). Furthermore, the problem of gas "clean-up" as a result of the discharge had to be solved.

As the target in a sealed-tube construction can now no longer be replaced at fairly short intervals as in the large-scale accelerators, an improved target had to be constructed for the 18600.

Regulation of Gas Pressure

The tube is initially filled with a mixture of deuterium and tritium and, on being ionised, both gases are accelerated and penetrate the target material ("drive-in" target principle). As a result, both deuterium and tritium enter into nuclear reactions with the bombarding ions. The pressure inside the tube is adjusted by means of an in-built "replenisher" containing a large reserve of D, T mixture, so enabling gas "clean-up" to be compensated and removing a further restriction on the life of the tube. The replenisher compensates for the reduction of pressure within the tube due to gas "clean-up" in the discharge, and for the spontaneous pressure rises which occur, for example, when previous occluded filler gas is released. It consists of a thin-walled nickel cylinder with a heater wire mounted inside. Around the heater is wound a titanium wire which is evaporated on to the inside cylinder wall as a fine powder when heater current is applied. During tube operation, the current through the same heating element is used to control the rate at which gas is released or absorbed from the titanium. The titanium deposit absorbs large quantities of hydrogen and its isotopes very quickly, but releases the gas when heated. The degree of control exerted by the replenisher is shown in Fig. 3.

Ion Source and Nature of Ion Beam

A Penning ion source was found to be ideally suited to this application. It functions at a very low gas pressure, down to 10^{-4}mm Hg, which is made possible using a special technique whereby the distance travelled by the ionising electrons is many hundred

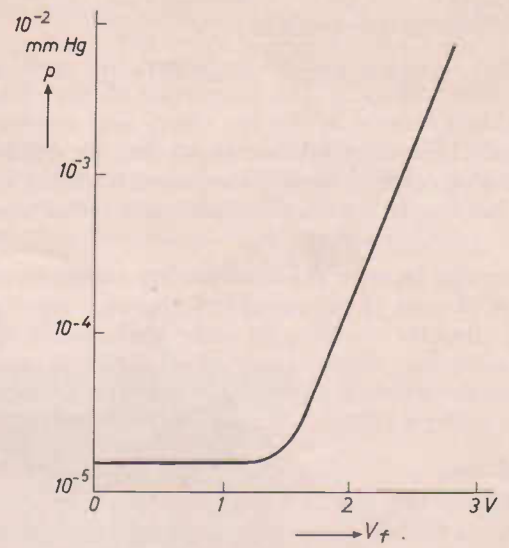


Fig. 3. Pressure p in the neutron tube, as a function of the voltage V_f across the filament of the hydrogen pressure regulator.

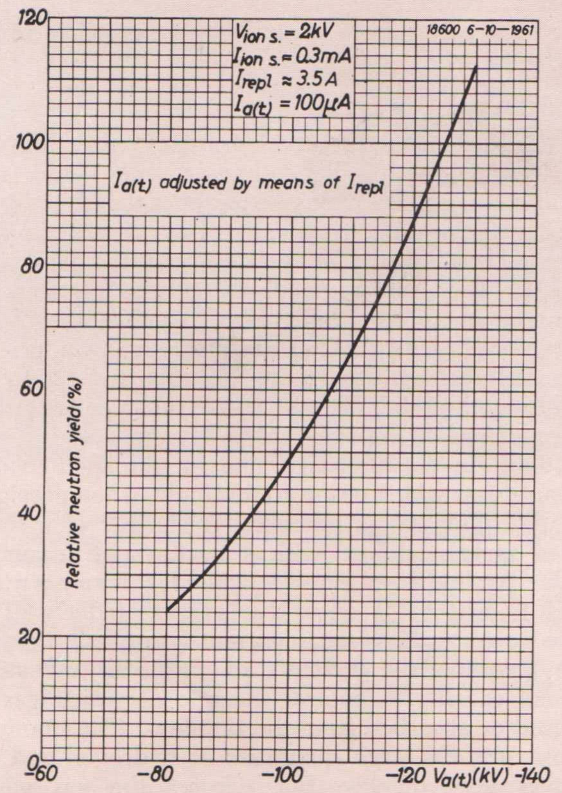


Fig. 4. Relative neutron yield as a function of target voltage for the 18600.

times greater than the electrode separation, allowing adequate collision frequency. This source has the further advantage of simplicity, no filamentary cathode being used. Although this source supplies mainly singly-charged molecular ions, which lowers the potential neutron yield, this is outweighed by the advantages of longer life, robustness and simplicity of construction and operation.

The ion beam is conical in shape, its apex angle being determined by the properties of the electron-optical lens formed by the ion source and accelerating electrode. The target is set up so that its whole surface is just covered by the ion beam, resulting in efficient loading of the target, and hence better neutron yield.

The tubular form of the accelerating electrode allows capture of most of the secondary electrons leaving the target. Besides resulting in other undesirable effects, these secondary electrons would otherwise give rise to X-radiation which is undesirable in many applications of the neutron tube.

Target

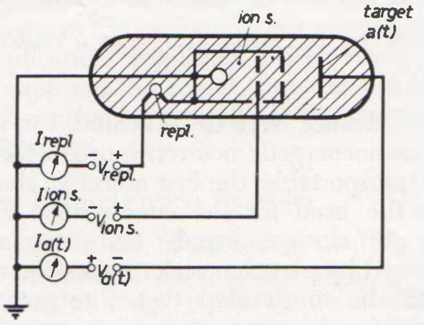
To bring about the D-T reaction deutrons must be shot into a tritium (gaseous) target. Thus some means must be found to occlude or anchor the target to a solid body. In the construction of the 18600, a "drive-in" type target is employed, which has basic advantages over some of the more conventional types. Through its use, the tube life ceases to be dependent on that of the target, and more effective initial tube degassing can be carried out. Life tests on production units under conditions considerably in excess of ratings have indicated negligible fall-off in reliability of operation, or in neutron yield, after periods exceeding 1000 hours.

However, despite considerably increased life, the usual type of "drive-in" target has a smaller neutron yield than other types commercially available, and thus steps have been taken in designing the 18600 to develop a "drive-in" target having an appreciably higher neutron yield. The target incorporated consists of an approximately 1 μm film of titanium evaporated on to a silver base. The titanium naturally absorbs and retains a very high concentration of hydrogen isotopes, whilst the silver backing has a low diffusion coefficient for hydrogen. This titanium target remains stable up to 200°C.

OPERATION OF THE 18600 NEUTRON BEAM TUBE

For an accelerating voltage of 125 KV and an ion current of 100 μA, a yield in excess of 10^8 n/sec is obtained, the energy of neutrons emitted at 90°C to the primary beam being approximately 14 MeV. The variation of neutron yield with target voltage is depicted in Fig. 4.

ABRIDGED TENTATIVE DATA



(*reference point for all voltages is the metal envelope*)

Ion-source voltage	2000 V	DC
Ion-source current	0.3 mA	DC
Replenisher voltage	1.5 V	
Replenisher current	3.5 A	
Target voltage	— 125 KV	DC
Target current	100 μA	DC
Neutron yield	min. 10^8n/sec.	

Limiting values (*absolute ratings*)

Ion-source voltage	min. 1500 V
	max. 2500 V
Ion-source current	max. 0.6 mA
Replenisher voltage	max. 3 V (measured directly at tube)
Replenisher current	max. 5 A
Target voltage	max. — 130 KV*
Target current	max. 125 μA
Ambient temperature	min. — 25°C
	max. + 55°C (determined by the HT cable)

* It is recommended that a 3 M Ω resistor be placed in the target supply line to protect the tube against oscillation build-up should HT supply break down.

The neutron yield can be adjusted to any desired value between zero and maximum by varying the accelerating voltage. Alternatively, the yield can be varied by adjusting the gas pressure within the tube or the voltage applied to the ion source. Of particular importance is the facility for stabilising the neutron yield—it generally suffices to maintain the ion source current constant, which can be arranged by a feedback connection employing replenisher control.

A pulsed neutron flux can be obtained by pulsing the ion source voltage, the minimum usable pulse duration being 5 μS. With pulsed operation the guaranteed yield can be increased to 10^9n/sec.

ANCILLARY EQUIPMENT FOR 18600

A high tension supply is required (e.g., Greinacher cascade generator) supplying 125 KV DC at currents ranging from 100 to 200 μA, and a power unit supplying 2 to 3 KV DC at 0.3 to 1.0 mA for the ion source. The hydrogen pressure regulator requires 0 to 2 V AC at currents up to 5A.

The neutron yield can be measured with any kind of radiation detector responsive to neutrons; some detectors will require preliminary calibrations. The neutron yield has been checked by Philips using a neutron activation method (refer to page 76) in an exact measurement requiring no calibration, which was also checked against the *method of associated particles* (as alpha particles are liberated at the same time as neutrons).

BF_3 PROPORTIONAL COUNTERS FOR SLOW (THERMAL) NEUTRONS

The use of plastic scintillators for fast-neutron detection has already been discussed(8) in the *Digest*, and further details are given in (1)(9). Now, the Philips ZP range of neutron proportional counters has been introduced utilising the B(n, α) Li reaction to detect slow neutrons in the flux range 10^{-4} to 10^5 n/cm²/sec. The counters in this range provide effective discrimination against gamma radiation as demonstrated by the typical operation quoted. The life expectation of the tubes under such operational conditions is in excess of 10^{11} counts, the life finally being determined by the consumption of the boron trifluoride gas filling in the action referred to, and by ionisation.

The capacitive loading of each tube should be kept to the minimum and, in order to prevent leakage, the tube should be kept dry.

The carefully purified and dried gas-filling is at a pressure of 70 cm Hg, and is enriched in B^{10} (a stable isotope of boron) to 96%. During manufacture, all measures have been taken to avoid poisoning of the gas during operation. These measures have resulted in tubes with long life expectancy and qualities which distinguish them amongst comparable types of other makes.

Connection to Counters

Each tube (excluding ZP1001) is fitted with a chassis-mounting MHV connector type MIL-UG-931/U, and a mating cable-mounting plug (MIL-UG-932/U) is also supplied. The cable recommended for use with the tubes is MIL-RG-59/U. The ZP1000 is shown in Fig. 5.

A plugless version of the ZP1000 (the ZP1001) is intended for those cases where a plug connection could well be dispensed with (e.g., where the tube will be directly connected to a pre-amplifier).

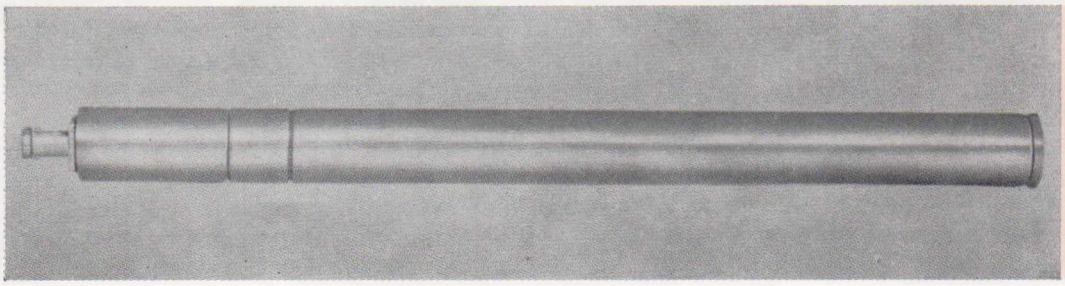


Fig. 5. BF_3 proportional counter type ZP1000.

Table 1—Summarised Performance and Dimensions of ZP Proportional Counters

(Development sample data)

	Flux Range (n/cm^2 per sec)	Approx. Sensitivity (cts. per n/cm^2)	Output Pulse Amp. (mV)	Background (cts./min)	ΔP max	ΔN max	Dimensions	
					P (%)	N (%)	dia. (mm)	sens. length (mm)
ZP1000 .. **ZP1001** ..	10^{-3} to 10^{4}	10 over operating range of V_b = 1600-2400 V	1-10 over range approx. 1700-2300 V	1 max.	14	2	25	250
ZP1010 ..	10^{-2} to 10^{5}	1 over operating range of V_b = 900-1900 V	1-10 over range approx. 1050-1600 V	0.1	8	2	12.7	100
ZP1020 ..	10^{-4} to 10^{3}	75 over operating range of V_b = 2300-3800 V	1-10 over range approx. 2700-3600 V	3	25	3	50.8	513

Materials

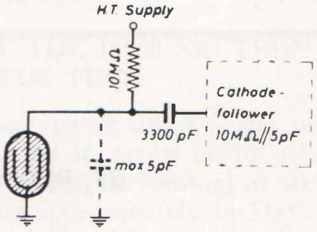
Cathode	oxygen-free copper, 0.4 mm
anode	tungsten, 50 μ dia.
bottom	Fernico, 0.5 mm dia.

Ambient

(at which values specified) .... 25°C

Circuit

(for which values specified)



SOME FIELDS OF APPLICATION FOR THE SEALED-OFF NEUTRON TUBES AND SLOW NEUTRON DETECTORS

Some typical applications of the 18600 are listed immediately below, and a discussion of the various corresponding techniques then follows.

- bore-hole logging for oil (also coal and mineral prospecting) at the site
- activation analysis with fast or thermal neutrons
- ground studies for highway, airport and similar constructions
- ground-water measurements in drainage and irrigation control projects
- subcritical reactor research
- fast reactor control
- fundamental nuclear research
- radiobiology
- radiochemistry
- production of radioisotopes
- training and education
- industrial applications including labelling of items for tracer work, moisture control of foundry sand, inventory of large stockpiles of coal and grain.

"Activation Analysis"

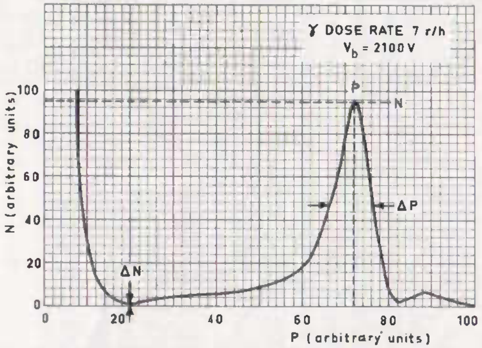
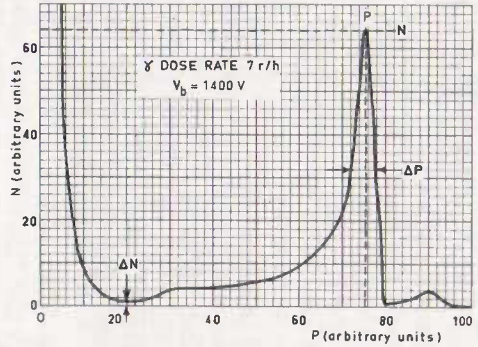
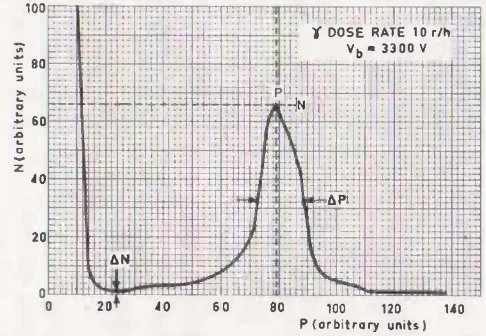
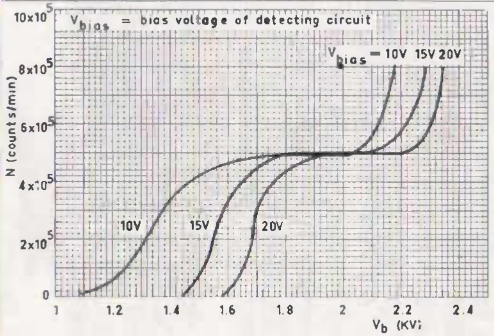
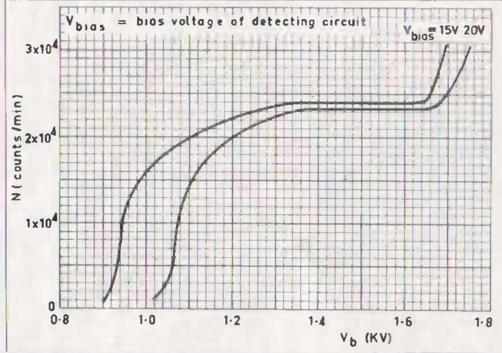
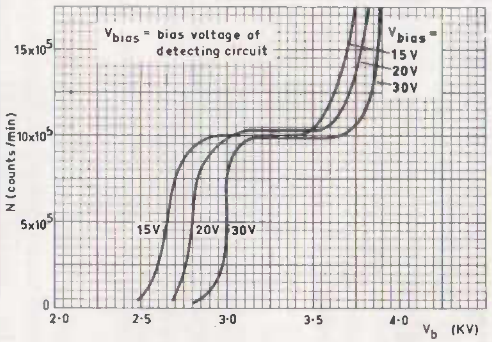
"Activation analysis"(10) implies the subjection of substances to irradiation in order to produce some type of nuclear reaction, resulting in the production of a radioisotope of the element to be determined. Since the radioisotope formed decays with its own characteristic radiations and half-life, this analysis technique can be very effective. The resulting beta or gamma emission can be detected using standard techniques. Of all the possible nuclear reactions, both slow and fast-neutron reactions have been most used in activation analysis, and hence the importance of a compact neutron generator such as the 18600. Besides applications involving the determination of microgram and sub-microgram quantities of many elements, neutron activation analysis can be used to determine certain "trace" elements(11) which present difficulties for other analytical techniques.

In many geological studies, detection of the major or minor, but not "trace" elements is of interest(12) and here activation analysis has the advantages of being non-destructive and of providing rapid average values for entire core samples. This results in great time-saving compared with other methods.

Fast neutrons derived from the 18600 can be slowed down (or "thermalised") using the hydrogenous moderator(18) materials mentioned in the introduction: these include ordinary water. Tabulated information is available(13)(14) on known thermal neutron activation cross-sections, which indicate the relative probability with which a given radioisotope will be formed when a substance is exposed to a source of neutrons. The sensitivity of analysis for a specific element can be computed from the neutron activation cross-section, isotope abundance and half-life.

Table 2—Typical Operation and Typical Performance Curves of ZP Proportional Counters

(Development sample data)

	ZP1000 & ZP1001	ZP1010	ZP1020
Operating Voltage (V)	2100	1400	3300
Gas Mult'n Factor.. ..	13	14	11
Dist. of Source from Tube (cm.)	10	15	6
Accompanying Gamma Dose Rate (r/h) ..	7	<7	<10
Approx. Pulse Amp "V_{pulse}" (mV)	4.5	4	4
Neutron Count Rate* "N" (counts/min) ..	5×10^5	2.3×10^4	10^6
Typical Differential Bias Curve			
Typical Plateau Curve..			

* bias setting in valley of differential bias curve.

Ambient	25°C
Source (in paraffin moderator)	10 mg. of Ra-Be.
Circuit	as in Table 1.

(An Ra-Be source produces a strong background of γ-radiation in addition to neutron emission.)

Atchison and Beamer(15) have applied activation analysis to the halogens, a large particle accelerator being used at that time.

Guinn and Wagner(16) have described the advantages of instrumental neutron activation analysis compared with conventional "wet" chemical neutron activation techniques employed for micro-concentrations. Instrumental techniques include identification of the isotope produced by beta energy, and half-life; gamma-ray spectrometry is also often used.

In principle, neutron activation analysis allows all geologically important elements to be identified.

Other Methods of Non-Destructive Analysis using Neutrons

Another distinct method of non-destructive analysis employing neutrons consists in using a gamma spectrometer(17) to investigate the gamma radiation generated during neutron bombardment of a sample, the gamma emission being attributed to either inelastic scattering of fast neutrons (the struck atoms becoming excited or ionised) — or to slow neutron capture (n, γ reaction). This method is then one of *directly* induced gamma emission. It has great potential, as gamma radiation can be detected more easily and more efficiently. A related technique is to use a pulsed neutron source such as the 18600 in order to exploit the delay between the gamma radiation generated by inelastic scattering of fast incident neutrons and that generated by elastic scattering of the neutrons thermalised by passage through a substance. *This technique allows fresh or salt water to be differentiated from mineral oil.*

Furthermore, techniques are being employed in which slow neutron detectors are used to detect the "back-scatter" of thermalised neutrons derived in the first place from a fast-neutron source.

All these methods, together with the activation methods described above, are highly suitable for geological investigations and oil prospecting—*the degree of mobility of the 18600 neutron tube making it possible to assay mineral samples in the field and its small size enabling it to be lowered into drill holes (together with a suitable detector). Moreover, it eliminates any possible radiation hazard above ground.*

Ellis(18) has described some of the above and other methods of "well-logging" including the detection of "back-scattered" photons to provide a profile of the strata. *He also describes a rapid technique for assessing the protein content of grain samples, using neutron irradiation.*

Fundamental Research

The simplicity of construction and operation of the 18600 make it an extremely useful tool for nuclear laboratory research. Investigations of elastic and inelastic scattering of fast neutrons, and slow neutron capture, together with the production and investigation of radioisotopes, are possible. The calibration of neutron spectrometers, Wilson cloud chambers, bubble chambers and nuclear emulsions can also be undertaken.

Reactor Studies

The facilities for pulsed operation provided by the 18600 make it eminently suitable for studying the properties of reactor materials in sub-critical rigs. Fast reactor control is also possible.

Miscellaneous Medical, Biological and Engineering Applications

Neutron irradiation is playing an increasingly important role in all these fields. For example, in medicine some types of neutron irradiation therapy are becoming important, notably use of the B^{10} (n, α) Li^{7} reaction for alpha-particle irradiation of brain tumours.

In engineering(10)(18), the ability to produce short-lived radioisotopes on the spot will be particularly important for processes and investigations involving radio-active tracers.

(This review has been compiled by A. J. Erdman of the "Miniwatt" Electronic Applications Laboratory.)

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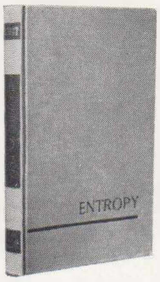

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