Wireless World

ELECTRONICS, RADIO, TELEVISION

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MARCH 1958

In This Issue

VOLUME 64 No. 3

PRICE: TWO SHILLINGS

FORTY-SEVENTH YEAR OF PUBLICATION

Offices: Dorset House, Stamford Street, London, S.E.1.

Please address to Editor, Advertisement Manager or Publisher, as appropriate.

Telephone: WATerloo 3333 (60 lines)

Telegraphic Address: "Ethaworld, Sedist, London".

PUBLISHED MONTHLY (4th Tuesday of preceding month) by ILIFFE & SONS LTD., Dorset House, Stamford Street, London, S.E.1. *Telephone:* Waterloo 3333 (60 lines). *Telegrams:* "Iliffepres, Sedist, London." *Annual Subscriptions: Home and Overseas,* £1 15s. 0d. *Canada and U.S.A.* $5.00. Second-class mail privileges authorised at New York, N.Y. BRANCH OFFICES: *BIRMINGHAM:* King Edward House, New Street, 2. *Telephone:* Midland 7191. *COVENTRY:* 8-10, Corporation Street. *Telephone:* Coventry 5210. *GLASGOW:* 26B Renfield Street, C.2. *Telephone:* Central 1265. *MANCHESTER:* 260, Deansgate, 3. *Telephone:* Blackfriars 4412. NEW YORK OFFICE: *U.S.A.:* 111, Broadway, 6. *Telephone:* Digby 9-1197.

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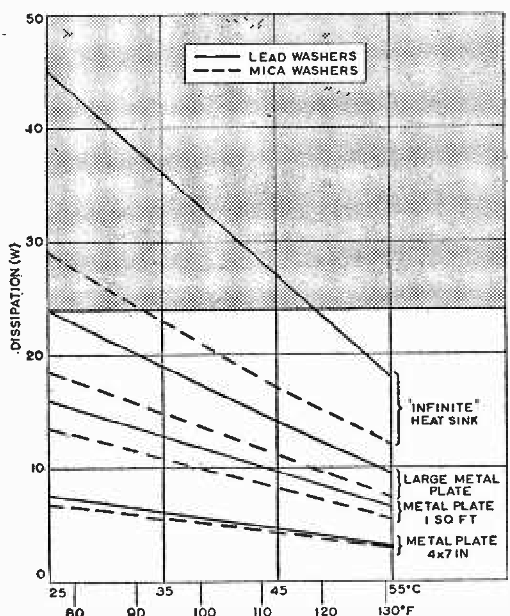
Transistor Heat Sinks for Audio Output Stages

The characteristics of semiconductors are temperature-dependent. If the maximum temperature rating of a diode or transistor is exceeded, the current through the device will rise, the temperature will be further increased, and so on cumulatively to destruction. The maximum temperature rating of a present-day transistor is, in fact, quite high, and in later types it will be higher still; nevertheless, it is necessary that designers should ensure that suitable temperature conditions are provided.

Temperature control is of particular importance in transistor power output stages, because the dissipation at the collector junction of power transistors is itself a substantial source of heat. The problem is well illustrated by the potentially unfavourable lot of the output transistor in a 'hybrid' car radio receiver. The transistor produces heat, and so do the valves; ventilation may be poor; and a parked car (which may be black) can soak up a great deal of heat from outside in summer sunshine. This example is extreme, but it is a useful basis for generalisation. Thus, the designer must consider:

(i) The power dissipation required in the circuit.
(ii) The amount of heat which the transistor will generate at this dissipation level.
(iii) The means of disposing of heat.
(iv) The surroundings, which may either assist or hinder the dissipation of heat.

In a car radio the transistor temperature can be held down in two ways. The transistor can be mounted away from the valves; and it can be provided with a 'heat sink', which is a metal mounting plate which conducts heat away from the transistor and radiates it into the surrounding air. The heat sink can conveniently act as a chassis for the speaker and the whole of the output stage, with a cable connection from the rest of the receiver.



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Heat sink design is based on the 'thermal resistance' θ of the metal parts through which the heat flows from the collector junction to the air. The first section of the heat-conducting path is the internal structure of the transistor, with a θ of about 1.0°C/W (Mullard OC16). This means that, for every watt of electrical dissipation, the collector junction will be 1.0°C hotter than the mounting base of the transistor.

Next is the θ of the contact between the mounting base and the heat sink. If the OC16 is mounted in a plain hole and secured with its fixing nut, θ is 0.3°C/W. If the hole is threaded, and thin tin-plated lead washers are used to give good mechanical contact, θ can be reduced towards 0.1°C/W. If, on the other hand, the transistor is insulated from its mounting (say by mica washers), θ may be as high as 0.7°C/W.

The remaining thermal resistances are those of the heat sink itself (its resistance to the spread of heat from the transistor mounting towards the edge), and of the contact between the heat sink and the air. The second of these is a complex quantity depending on surface texture, colour, and air flow. The first is a function of area, material, and thickness. Typical values for the sum of these two resistances lie between 1.5 and 3.5°C/W.

If all the successive thermal resistance values are added together, and the sum is multiplied by the wattage dissipated at the collector junction, the answer is the temperature difference between the collector junction and the air. Thus the junction is held above ambient temperature by that amount. This margin can be reduced by using a heat sink with lower θ and by providing suitable surroundings.

It is possible, in some industrial installations, to use a large thick heat sink in conjunction with water-cooling. Such an arrangement is known as an 'infinite' heat sink, and it allows the transistor to operate (for a given dissipation) with minimum temperature rise above ambient. But this is an ideal which is obviously not attainable in normal practice.

A suitable heat sink is necessary to keep the junction temperature within limits and thus to prevent thermal runaway. It may also allow the transistor to be operated at a higher dissipation (within its wattage rating) without exceeding the temperature limit. Some possible ways of operating the Mullard OC16 are shown in the graph. Any point on the graph will produce the maximum rated junction temperature of 75°C. Thus, with a 'large metal plate' and an ambient temperature of 35°C, a dissipation of about 19W will produce a junction temperature of 75°C. If the ambient temperature is 45°C, then 14W will do the same thing. If, with this ambient temperature, mica washer mounting is used, then heat drainage is less efficient and a dissipation of only 11W gives 75°C. The 'infinite' heat sink is so efficient that no less than 45W is necessary to raise the junction temperature to 75°C when the ambient temperature is 25°C. This wattage is, in fact, well outside the present 24W dissipation rating of the OC16, and is put in only for illustration.

The detailed method of calculating allowable dissipations under various temperature conditions is given in power transistor data sheets. Practical designs of heat sink are based on such calculations and on temperature measurements under actual working conditions.

Mullard T.S.D. DATA and PUBLICATIONS SECTION, MULLARD LTD., MULLARD HOUSE, TORRINGTON PLACE, LONDON, W.C.1
MVM 387

MARCH 1958

Vol. 64 No. 3

Wireless World

Radar History

WHEN the full and final history of radar comes to be written—and that will not be until many facts are made public which so far have been withheld in this and other countries on real or imagined grounds of "security"—it will be found that development has taken place in several well-marked phases.

First there was the acquisition of the knowledge of the basic physics of electromagnetic radiation, theoretically by Faraday and Clerk Maxwell and experimentally by Hertz.

Then followed the idea of using echoes of wireless waves to reveal the presence of ships and other objects. Although Hulsmeyer was granted a patent in 1904 for apparatus designed for this purpose it could not, with the means then available, have been more than an obstacle detector and does not qualify as a radar system. This may be said of many other re-discoveries of the basic idea during the second phase, which lasted up to about 1935. Some were based on the observed interference effects from reflection of short waves from aircraft, and made use of continuous-wave methods similar to those of Appleton and Barnett for measuring the height of the ionosphere. Others, based on the pulsed ionospheric exploring system of Breit and Tuve, obtained limited success, chiefly on ships at ranges of a few miles. Performances on aircraft were quite inadequate to meet the needs of an early warning system, having regard to the speeds of military aircraft then in service.

The third and most significant phase began somewhere between 1930 and 1935 when Great Britain, in common with all the Great Powers, began intensive development of radio methods of detection. In many countries the work was carried out on an empirical basis and progress, though positive, was slow. Great Britain owes the supremacy which she clearly held at the outbreak of war, first to a sound and far-sighted scientific appreciation of the problem which is epitomized in a memorandum from R. A. Watson-Watt (27th February, 1935) to the Committee for the Scientific Survey of Air Defence. This document, which is reproduced in an appendix to a recently published book.* states the basic power requirements and recommends the use of a pulsed system on frequencies for which the required power outputs and receiver sensitivities could be realized by known techniques. A second and no less important factor was a determination to stick to this programme and to resist the temptation to explore the many attractive side tracks which opened up during the course of the work. As Sir Robert succinctly put it "Give them the third best to go on with; the second best comes too late, the best never comes." The pioneer work of this crucial third phase was carried out by research physicists of the Radio Research Station, D.S.I.R., in collaboration with serving officers of the R.A.F., and the result was an integrated early warning and tracking system which went on 24-hour watch from September, 1938.

By present standards, the world's first radar chain may appear to have had many of the "string and sealing wax" characteristics of the research laboratory, but it was a vital factor in the winning of the "Battle of Britain" which, amongst other things, permitted the development of a fourth phase—the collaboration of the radio and electronics industry with Government scientists in bringing to fruition the many promising ideas which had been put "in the ice box" during the struggle for survival. This collaboration, which had already begun in the erection of the chain stations, continued until the end of the war and produced the sophisticated devices which were put into operation from six months to two years ahead of anything our enemies could devise in retaliation.

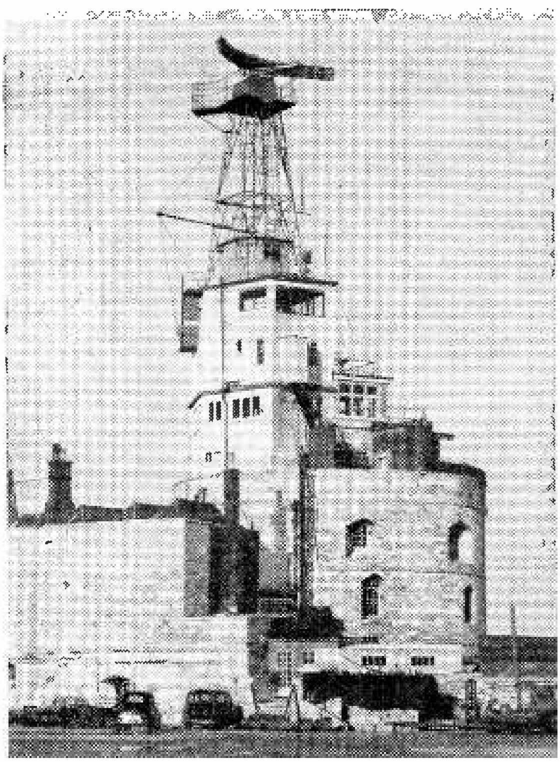
The fifth phase, the application of the radar arts to peace—including speed traps for motorists and the tracking of satellites—is still an open chapter.

The future historian should be grateful for the wealth of scientific, military, and biographical detail which Sir Robert has poured out in this book, but he will have to devise his own equivalent of a radar system for finding the way to the facts he wants. When he chooses, Sir Robert can write with crystal clarity, but too often he indulges a weakness for the tortuous allusion which tests the reader's memory of what has gone before or must await something which is to come later. This is a book which cannot be skimmed; it must be read the hard way.

* "Three Steps to Victory," by Sir Robert Watson-Watt (Odhams Press, Ltd.).

Radio Control

INTEGRATED SYSTEM OF SURVEILLANCE RADAR



Decca 25-ft scanner on its tubular steel tower at the Calshot signal station.

DURING the early part of this year a new radio control system and information service was formally brought into use by the Southampton Harbour Board, the inauguration ceremony being performed by the Rt. Hon. Harold Wilkinson, M.P., Minister of Transport and Civil Aviation.

It is an integrated system of high-definition surveillance radar and v.h.f. radio-telephony, which presents the duty operations officer located in the Calshot signal station with a complete "picture" of the movements and positions of all vessels within the port area and its immediate approaches.

The control console, which is shown in one of the illustrations, is crescent-shaped and has three 15-in. radar display units each capable of showing any of the five operational areas which make up the planned coverage of the station. These are Southampton Water, the West Solent, East Solent, the controlled anchorage and a general overall picture of shipping from the Needles to the Nab Tower and taking in an area some 2 to 3 miles south of the Isle of Wight.

Radar information is supplied by the Decca high-definition, 3-cm harbour surveillance radar, Type 32, the 25-ft scanner for which is mounted on a tubular-steel structure on the top of the Calshot Signal Station. This aerial is of parabolic section, slotted to reduce windage to a minimum and has a horizontal beamwidth of less than 0.3°. Associated with a pulse length of 0.05μsec it provides a radar display of the highest quality and definition. The comparatively narrow vertical beamwidth of 4° is adopted as a wider one would only be wasteful of power and liable to introduce undesirable rain clutter.

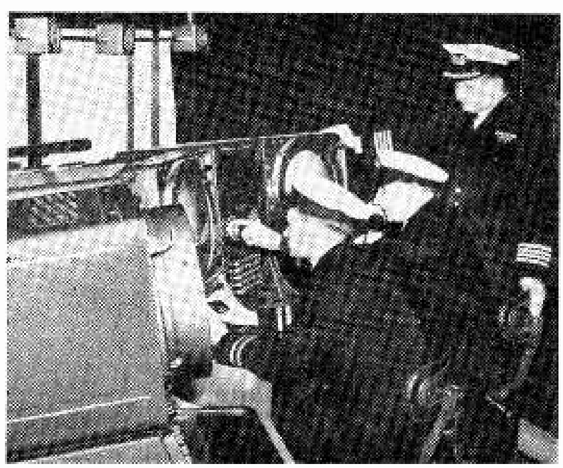
Reliability is ensured by duplicating the radar transmitting and receiving equipment with remote control for immediate changeover in case of emergency. The use of a high-gain aerial enables the required coverage and performance to be achieved with a nominal transmitter peak power of 10kW.

In addition to range rings and bearing graticule centred on Calshot each display tube has one bright, inter-scan line which can be varied in length, bearing and origin and provides a very accurate and convenient method of measuring distances between any two points on the displayed radar picture.

The background information provided by the several radar displays enables the duty controller to pass to ships' masters and pilots information and instructions relevant to the movements of individual vessels and for this the VHF/RT is employed.

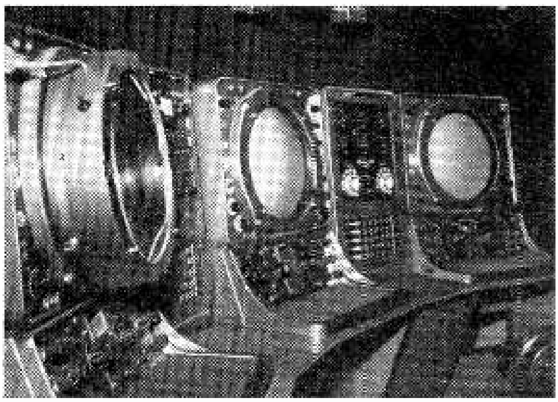
The equipment was supplied by Marconi's and for the shore stations, of which there are five suitably dispersed throughout the harbour area, 6-channel, crystal-controlled sets are used, each remotely controlled from the Calshot operations room and radiating about 25 watts effective power. The frequencies allocated for this service lie in the band 156.3Mc/s to 161.7Mc/s with 156.8Mc/s reserved for calling and safety purposes. Hitherto the majority of v.h.f. marine radio-telephones have used amplitude modulation but the Southampton installation employs frequency modulation. This is believed to be the first implementation of the agreement reached by all north-western European countries at the International Maritime VHF Radio Conference held at the Hague in January 1957, where it was agreed

Nerve centre of the new Southampton port operations and information service is located at the Calshot signal station.

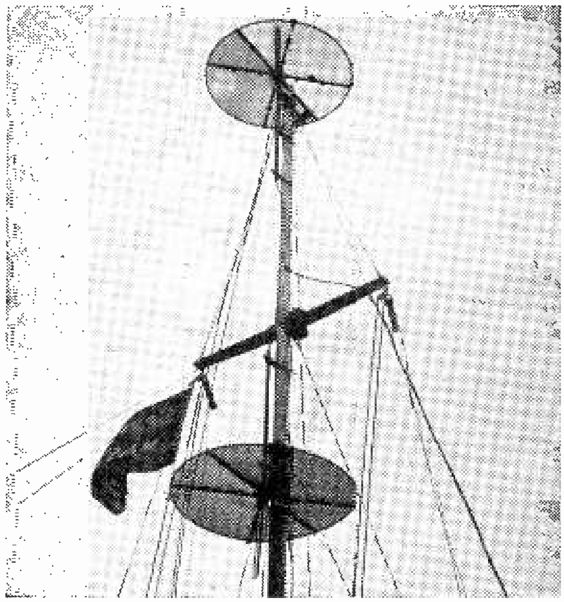


at Southampton Harbour

AND VHF/RT FOR CONTROL AND INFORMATION OF SHIPPING AND AIRCRAFT



Decca radar displays and Marconi VHF/RT control units in the information room.



Transmitting and receiving aerials mutually screened by wire-mesh ground planes mounted on the harbour patrol launch "S.H.B. Triton."

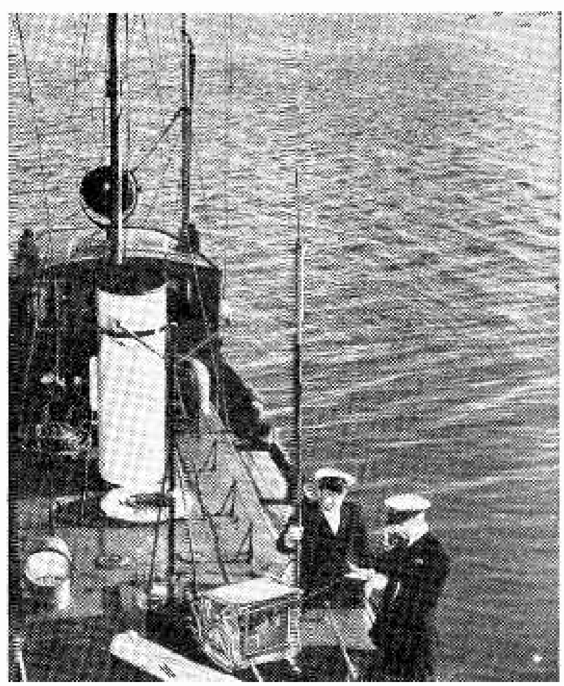
that f.m. should be employed for ship-to-shore VHF/RT services. Representatives from U.S.A., Italy and Canada were also present.

The port operations officer is assisted by a patrol officer in a launch, the "S.H.B. Triton," which is fitted with a marine radar, echo sounding and VHF/RT. The patrol launch normally precedes vessels entering or leaving the port to ensure there is no obstruction by small craft in the harbour. The R/T equipment on the "Triton" consists of two 5-channel, 10-watt transmitters/receivers, Type HP86B operated from d.c. Since these are required to operate simultaneously and possibly on adjacent channels, special care has been taken in mounting the transmitting and receiving aerials. These are vertically polarized, ground-plane systems mounted one above the other on the "Triton's" mast and the ground-plane is reinforced by wire mesh. Further isolation is achieved by mounting the unipole of the upper aerial on top of the ground plane and the unipole of the lower below the ground plane, as shown in one of the illustrations.

In common with the practice now current at most large airports all radio-telephone messages are recorded on magnetic tape, for which purpose an 8-channel automatic recorder made by Thermionic Products has been installed. Times of all messages, received and transmitted, are recorded for future reference.

Since Southampton is an airport as well as a seaport, close liaison is maintained between the port duty officer in the Calshot control centre and the duty flying officer who is in direct R/T communication with the flying boats using Southampton. Integration of the movement of shipping and aircraft is assisted by fitting the aircraft control launch, "S.H.B. Sharb," with a transportable version of the HP86B R/T equipment operating on the same five channels.

Marconi 10-watt transportable radio telephone aboard "S.H.B. Sharb."



WORLD OF WIRELESS

University Scholarships

A NEW university scholarships scheme, providing up to 20 awards each year for boys leaving school or completing their National Service, has been introduced by the English Electric group of companies, of which the Marconi group is part.

The scholarships provide for three years at a university, during which a scholar will receive £450 a year, two years' industrial training (one of which can be taken before entering the university) and two years' experience in a responsible engineering post. Scholars may read for an honours degree in engineering, applied science, mathematics or any technology relating to the engineering industry.

The first scholarships will be awarded by selection in the 1958-59 academic year and applications from boys having obtained a place at a university must be made through headmasters to the Controller of Education, English Electric Co., Marconi House, Strand, London, W.C.2, by March 31st.

Television Show

RESEARCH, rather than domestic reception, is the keynote of the annual exhibition organized by the Television Society and this year's show—the 15th—is no exception. In all 25 exhibitors, listed below, will be participating.

The three-day exhibition (March 4th to 6th) is again being held in the Royal Hotel, Woburn Place, London, W.C.1. Admission is limited to members and the press on the first day (11.30 to 8.0), but tickets for the other two days (12.0 to 8.0 and 12.0 to 7.0, respectively) are obtainable from exhibitors, members and the Society (166, Shaftesbury Avenue, London, W.C.2).

Aerialite
B.B.C.
Belling & Lee
Bush
Chapman & Hall
Cintel
Cossor
Ekco
Ever Ready
Ferguson
G.E.C.
Hallam, Sleigh & Cheston
Livingston Laboratories
Mullard
Murphy
Norwood Technical College
Post Office Engineering
Siemens Edison Swan
Standard Insulator Co.
Telcon
20th Century Electronics
W. Vinten
Wayne Kerr Laboratories
R. W. Wells (Member)
Wolsey Electronics

Audio Fair

TICKETS for the London Audio Fair (Waldorf Hotel, April 18th to 22nd inclusive) are again being issued free through exhibitors and audio dealers. Readers of *W.W.* can obtain tickets from the editorial office. They are dated for specific days and applicants must state the day of visit and, if possible, give an alternative. Applications must be accompanied by a stamped addressed envelope (6in by 3½in).

The Fair will be open daily from 11.0 to 9.0, but admission up to 4.0 on the first day is limited to the trade.

The British Sound Recording Association has decided not to hold its own audio exhibition this year, but will be participating in the Audio Fair.

Export-Import Figures

A RISE of over £3M in the exports of radio equipment during 1957 compared with the previous year, brought the total to a new record of £43.5M. In the following table the export figures (provided by the R.I.C.) for the two years are compared with the import figures culled from the Board of Trade "Trade and Navigation Accounts".

	Exports		Imports	
	1956	1957	1956	1957
Transmitters, nav. aids, etc.	16.5	16.0	2.7	2.7
Valves and c.r. tubes	3.5	3.9	3.0	3.6
Domestic receivers	3.8	3.6	0.4	0.4
Sound reproducing gear	7.6	9.9	—	—
Components	8.7	10.1	—	—
Unclassified radio gear	—	—	3.6	4.1
	£40.1M	£43.5M	£9.7M	£10.8M

It will be seen that exports of sound reproducing equipment and components continued to rise. It has been pointed out that the decline in the export of receivers is to some extent accounted for by the fact that several British manufacturers are now assembling sets in consumer countries and this also accounts for part of the rise in component exports.

The increase in imports was mainly in "glassware". Imports of cathode-ray tubes increased by over 100%, bringing the 1957 total to over £1.6M.

Technical Writing Awards

WITH the object of encouraging technical writing to make more widely known British achievements in radio and electronics the Radio Industry Council awards annually up to six 25-gn premiums.

The recipients of the five awards for articles published in 1957, who will be receiving the premiums at a luncheon on April 10th, are listed below, together with the titles of the winning articles.

E. N. Shaw (R.R.E.) "Heat Control in Electronic Equipment" *Electronic Engineering*, Jan.-Mar.
E. J. Gargini (E.M.I.) "An Alternative Colour TV System" *Wireless World*, Aug.
L. Atherton (Mullard) "Cleaning by Ultrasonics" *British Communications & Electronics*, March.
E. J. P. Long "Speed Control in Industry" *British Communications & Electronics*, Nov. and Dec. and Jan. 1958.
L. W. D. Sharp (Plessey) "Components for Printed Circuits" *British Communications & Electronics*, April.

Forthcoming Events

THE following should be added to the "Dates for your *W.W.* Diary" published in January:—

Production Exhibition Olympia Grand Hall, London, W.14.	**May 12-21**
1st European Television Exhibition Park Lane House, 45, Park Lane, London, W.1.	**May 19-24**
International Congress on Video Techniques Namur, Belgium.	**June 10-13**
French Components Show Parc des Expositions, Porte de Versailles, Paris.	**June 20-26**
Electronics Exhibition and Convention Manchester College of Science and Technology.	**July 10-16**
Irish Radio and Television Show Mansion House, Dublin.	**Sept. 23-27**
Convention of Scientific Instrument Mftrs.' Assoc. Majestic Hotel, Harogate.	**Nov. 6-9**

Orkney's Television and V.H.F. Station.—As already announced the B.B.C. proposes to build a combined television and v.h.f. sound broadcasting station in Orkney to serve the Orkney Islands and the northern coast of Caithness. It is considered that the best point from which to relay signals from the main network to the Orkney station is near Wick. The installation at Wick will be designed to provide not only the radio link to the Orkney transmitter but also radiate the v.h.f. sound and television services in Caithness.

Music by Wire.—It is announced that the P.M.G. is prepared to consider applications from individuals and companies for licences to distribute music by wire to business premises, but not to private homes. These licences differ from the Broadcast Relay Licences in that live or recorded broadcast programmes will not be permitted. Licensees will themselves have to provide the wires from the music distribution centres to their customers' premises, but Post Office lines may be rented for linking music distribution centres one with another. The fee varies according to the number of subscribers.

Six-metre operation by selected amateurs in this country in connection with the International Geophysical Year, is being permitted by the P.M.G. for an experimental period of six months. They will operate on 52.5 Mc/s. This is at the top end of television Channel 2 and transmitters in certain areas will, therefore, be permitted to use the frequency only outside television transmitting hours. Further information is obtainable from the R.S.G.B., to whom applications for permission to operate must be made.

Broadcast receiving licences increased by 219,650 during 1957. The December figures, with in brackets the corresponding figures for 1956, were: sound-only 6,892,983 (7,864,030); combined TV and sound 7,760,794 (6,570,097); overall total 14,653,777 (14,434,127).

"Low-Cost High-Quality Amplifier" is the title of the 28-page booklet in which is reprinted P. J. Baxandall's amplifier, described in *Wireless World* in March and April last year, and his pre-amplifiers published in 1955 and 1957. The booklet is obtainable from our publishers, price 3s 6d (postage 6d).

Binding "W.W."—As announced last month, the index to Volume 63 is now available, price 1s, by post 1s 3d. Binding case and index costs 7s 6d (postage 1s 6d). Our publishers will undertake the binding of readers' issues, the inclusive cost being 25s. Copies should be sent to Iliffe & Sons, Ltd., Binding Department, c/o 4/4a, Iliffe Yard, London, S.E.17, enclosing a note of the sender's name and address. A separate note, confirming despatch, together with remittance, should be sent to the Publishing Department, Dorset House, Stamford Street, London, S.E.1.

An instruments exhibition is being staged by Airmec at the Napier Hall, Vincent Street, London, S.W.1, from March 24th to 27th. Tickets are obtainable, gratis, from Airmec, Ltd., High Wycombe, Bucks.

An audio exhibition is being held in the Midland Hotel, Manchester, on March 1st and 2nd. It is sponsored by the British Amateur Tape Recording Society. Admission is 2s.

Symphony de Luxe Tape Recorder, Type A.—We have been asked to point out that owing to a typographical error, the price of this instrument in the advertisement of Northern Radio Services on p. 68 of the February issue was given as 25 guineas. It should have been 52 guineas.

"Design for a Folded Corner Horn" (February issue).—The expression for the reactance of an acoustical volume capacitance given in the second paragraph of the right-hand column on page 60 should be multiplied by ρ. The 34-in dimension in Fig. 5(b) is a radius for the front portion.

Audio Demonstrations.—In addition to the normal programme of lecture meetings held by the British Sound Recording Association a series of demonstrations of audio recording and reproducing equipment is being arranged. The first was held in February, when Dulci equipment was demonstrated, and the next will be on March 3rd at 7.0 at the Royal Society of Arts, John Adam Street, London, W.C.2, when Pilot equipment will be demonstrated.

Radar Association.—It has been decided to include the word electronics in the title of the organization and it is now known as the Radar & Electronics Association. The last meeting of the present session will be held on March 12th in the Anatomy Theatre, Gower Street, London, W.1, when Professor A. C. B. Lovell will speak of the part played by the Jodrell Bank radio-telescope in tracking the artificial earth satellites. Information on the Association's activities is obtainable from 83, Portland Place, London, W.1.

Printed circuit techniques are being covered in the course of 10 lectures given by F. Hicks-Arnold (Cossor) at the Twickenham Technical College on Mondays. The course, for which the fee is £1, began on February 17th.

A concert of live and recorded items, including some stereophony, is being given in the Great Hall of the Blackwell Secondary Modern School, Headstone Lane, Harrow, Middlesex, on March 14th. The audio equipment is being lent by Lockwood & Co., of Lowlands Road, Harrow, Middlesex, from whom programmes price 2s are obtainable. Proceeds are for the school swimming pool.

Personalities

Sir Thomas Spencer, M.I.E.E., who last September completed 50 years' service with Standard Telephones and Cables, has relinquished his position as managing director and is succeeded by **F. C. Wright.** Sir Thomas continues as chairman of the company and its subsidiaries, which include Standard Telecommunication Laboratories, Kolster-Brandes and International Marine Radio Company.

T. E. Goldup, C.B.E., M.I.E.E., this year's president of the I.E.E., and **W. K. Brasher,** I.E.E. secretary, are due to leave London on February 28th to attend the Commonwealth Engineering Conference in Australia in March. On the outward journey they will be attending meetings in Iraq, India, Ceylon and Malaya. After the Commonwealth Conference they will go on to New Zealand and on the return journey will stop in Vancouver and Toronto on their way to the Conference of Engineering Societies of Western Europe and the U.S.A. in New York on April 28th.

A. A. Kay, A.M.Brit.I.R.E., has been appointed assistant chief engineer of the radio and television division of the Plessey Company. Before joining Plessey he was manager of the engineering and development department of RCA Great Britain, Ltd., and previously deputy head of Ultra's radio and television development department.

Alexander Rubach is appointed managing director of Pena Industries' new company, Penco Research & Development Co., Ltd., formed to co-ordinate engineering development and design within the Pena group. Towards the end of the war Mr. Rubach was seconded from the army to the Ministry of Supply for guided weapons research and since 1946 his positions have included those of engineer-in-charge of the electronics laboratory of the Anglo-Iranian Oil Company's Engine Research Section, senior development engineer of All-Power Transformers, where he was responsible for the engineering, design and manufacture of MOSAIC (Ministry of Supply automatic computer), and head of the experimental engineering department at the G.E.C. Applied Electronics Laboratories, Stanmore.

E. Lloyd Thomas, B.Sc., A.C.G.I., M.I.E.E., has joined R. B. Pullin & Co. as chief development engineer. After obtaining his degree from London University in 1937 he joined Plessey's development laboratory where throughout the war he was mainly concerned with cathode-ray direction-finding gear. In 1945 he went to Sperry Gyroscope Co. as a development engineer, and before leaving them in 1952 was equipment engineer on guided weapon control systems. Since then Mr. Thomas has been chief research engineer with Short Brothers & Harland (Belfast), where he was responsible for the development of the Short analogue computer.

E. L. THOMAS

R. H. MINNS

R. H. Minns, A.M.I.E.E., who for the past 16 years has been in the B.B.C. research department at Kingswood Warren, has joined Hatfield Instruments, Ltd., of Horsham, as technical director. He was at one time in charge of the radio-frequency measurement laboratory of the B.B.C. research department and has done a considerable amount of work on aerial design—particularly v.h.f. and u.h.f. **S. G. Sitton,** who has been manager of the company for the past 2½ years, has also been elected to the board of directors.

Isaac Wolfson has announced that with a view to the development of business at home and overseas, particularly in the United States, he has become the chairman of Collaro, Ltd., which is a member of the G.U.S. Group.

C. Collaro, O.B.E., who, following his resignation from Collaro, Ltd., recently became chairman of Camp Bird Industries, has now succeeded **B. R. A. Homfray Davies** as managing director of the company, and as chairman of Hartley Baird, Ltd., a member of the Camp Bird group. Mr. Homfray Davies resigned from these positions and the joint managing directorship of Hartley Baird at the end of January.

M. H. Evans, A.M.Brit.I.R.E., formerly of the Ministry of Supply and until recently a director of Epsylon Research & Development, Ltd., has formed, in collaboration with **K. W. Shipman** and **G. J. Shipman,** M.A.(Cantab.), K.G.M. Electronics, Ltd., to specialize in precision mechanical and electronic equipment. The general manager is **E. D. Parchment,** A.M.Brit.I.R.E., formerly of the Decca Record Co. and more recently a director of Epsylon Sales and Service, Ltd., and the chief engineer, **D. O'C. Roe,** B.Sc.(Hons.), who was at T.R.E., Malvern, during the war and subsequently chief electronics engineer at Birmingham Sound Reproducers, Ltd. More recently he was with Epsylon Research & Development, Ltd., and S. E. Opperman, Ltd.

W. West, O.B.E., B.A., M.I.E.E., who recently retired from the Post Office Research Station, where he had been staff engineer since 1946, was well known in the field of electro-acoustics. He had been chairman of the acoustics group of the Physical Society and the acoustics committee of the International Organization for Standardization and of the electro-acoustics committee of the Medical Research Council. During the war he was responsible for the design and production of emergency and permanent radio stations for both overseas and internal civil and military communications. His original work in electro-acoustics included the free-field calibrations of microphones and the design of the first artificial ear for measuring the response of telephone receivers. He had been in the Post Office for 35 years.

OUR AUTHORS

Dr. W. D. Cussins, whose article on the mechanics of electronics is on page 133, is in charge of the service department of Cussins & Light, the well-known electronics and electrical firm of York, which he joined in 1953. From 1944 to 1947 he was at Cambridge where he took the two parts of the mechanical sciences tripos, obtaining a first in both parts and the Charles Lamb Prize for the best performance in electrical engineering. He then spent two years in the E.M.I. research laboratories on research on high-power klystrons before returning to Cambridge to undertake research for his Ph.D. degree. His thesis was on the effects of ionic bombardment on germanium.

E. Moston Kenny, who describes a system for suppressing the "bright spot" which appears on television tubes on switching off the set, is engineer in charge of the applications laboratory of Morganite Resistors, Ltd. He was previously a development engineer in Plessey's chemical and metallurgical division. During the war he worked on Army signals equipment and associated test gear at the Inspectorate of Electrical and Mechanical Engineering (M.o.S.), Chislehurst, and was later in the Health Physics Electronics group at A.E.R.E., Harwell.

Clement Brown, author of the article on the magneto-dynamic pick-up, is in the technical-commercial department of Philips Electrical, Ltd., where he is concerned with the development of sound reproducing equipment. Before joining Philips in 1956 he worked on the design and development of high-fidelity products at E.M.I. and Plessey.

P. L. Burton, B.Sc., who, with J. Willis, describes some unusual transistor circuits, has been in the guided weapons division of English Electric since graduating in physics from University College, London, in 1951. His co-author **J. Willis,** B.Sc., joined the division, of which **L. H. Bedford** is chief engineer, in 1953, having spent three years in the R.A.F. after graduating in physics from Imperial College, London, in 1950.

OBITUARY

F. H. Robinson, Comp.Brit.I.R.E., honorary secretary of the Radio Industries Club, died suddenly on January 30th at the age of 56. Known affectionately throughout the radio industry as "Robbie," he had been on the staff of Odhams Press since 1922, first as editor of *The Broadcaster* (now *Electrical and Radio Trading*) and, since the war, as adviser in electrical and radio matters to the *Daily Herald*, *The People* and *Sporting Life*.

John Hytch, for many years a senior member of the press and publicity department of the B.B.C., which he joined in 1927, died on February 9th, aged 59. Since his retirement from the Corporation in 1955 he had been London representative of the Irish journal *Radio Review*, and latterly was adviser on broadcasting to the Gas Council.

Unusual Transistor Circuits

By P. L. BURTON, B.Sc., Grad.Inst.P., and J. WILLIS*, B.Sc., Grad.I.E.E.

Gating, Limiting and Other Operations, Mainly for Pulse Work

MOST electronic circuits can be based equally well upon valves or transistors, but there are some where the special properties of transistors are particularly advantageous. We have set out to describe a few such circuits here, concentrating on physical explanations of circuit action and the main features of design rather than on rigorous mathematical treatment.

Voltage Catching Circuits.—The diode voltage "catching" or limiting circuit is probably quite well known to many readers. However, its action is worth describing briefly, the better to compare it with its transistor counterpart.

A typical circuit is that of Fig. 1. A resistor R_L is fed with a varying current I. To prevent the

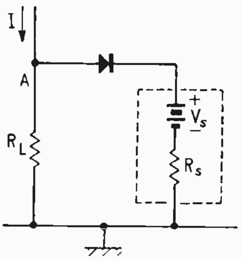


Fig. 1. Diode voltage catcher.

potential of A (at the upper end of R_L) from appreciably exceeding a given voltage V_s a diode is connected from A to a source of potential V_s. When the current exceeds the critical value $I_s = V_s/R_L$, the diode conducts; the incremental resistance of the circuit measured at A is thus now R_L in parallel with $R_d + R_s$, where R_d is the diode incremental forward resistance and R_s is the internal resistance of the source. Clearly, this must be very much less than R_L if catching is to be effective. Typical values of R_d and R_s are respectively 500 Ω (at 1 mA) and 1 kΩ, so effective catching cannot take place if R_L is less than about 15 kΩ.

The transistor catching circuit is shown in Fig. 2. So long as the current I is less than I_s the emitter of the transistor is at a lower potential than its base, so the transistor is cut off.

As soon as the potential at A becomes slightly greater than V_s, however, the transistor conducts and places an incremental resistance $r_e + (r_b + R_s)(1 - \alpha)$† in parallel with R_L. Typical values for 1 mA emitter current are $r_e = 20\,\Omega$, $r_b = 1000\,\Omega$. $(1 - \alpha) = 0.02$, so for a voltage source resistance of R_s of 1000 Ω the resistance placed in parallel with R_L is 60 Ω, a twenty-five-fold improvement over the diode case. Note that the current diverted from R_L mostly passes out through the collector of the transistor, which is taken to a suitable negative supply. (The presence of current in this lead may be used as an indication that catching has taken place.) For similar performance to the diode circuit, R_s can be much larger. If R_s is much greater than r_b, the incremental resistance of the catcher becomes $R_s(1 - \alpha)$, i.e. about $0.02\,R_s$, so that from this point of view R_s is limited only by the maximum acceptable incremental resistance. A further limitation, however, is imposed by the collector leakage current I_{co} which flows through R_s and makes the effective catching potential equal to $V_s - I_{co}R_s$. Since I_{co} varies rapidly with ambient temperature**, and considerably between transistors, R_s has usually to be chosen to keep $I_{co}R_s$ small over the operating temperature range of the circuit.

It is important to realise that the impedance-transforming property described in the last paragraph arises from the power amplification of the transistor, and hence that the frequency response of the transistor must be suitable for the rise time of the waveform applied to the catcher. If a very fast edge is applied to an audio-frequency transistor, a relatively long time is required for the catcher to operate and overshoot will occur. With the Mullard OC45 the catching is entirely satisfactory with rise-times of about a microsecond.

The circuit shown is of course suitable only for limiting positive voltage excursions. The corresponding circuit for negative excursions, Fig. 3, requires an n-p-n transistor, and, like many other elegant devices, must await their general availability.

Transistor Pump Circuit.—The diode pump circuit is a well-known device for generating a

**I_{co} doubles for approximately every 10 deg C rise in temperature. A typical figure (Mullard OC71) is 5μA at 20 deg C.

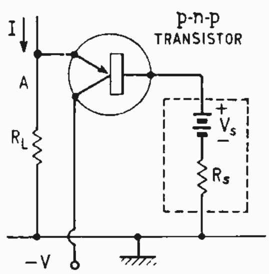


Fig. 2. Transistor voltage catcher. This uses a p-n-p transistor and limits positive excursions.

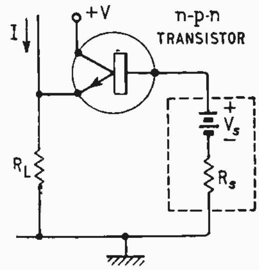


Fig. 3. A transistor voltage catcher using an n-p-n transistor for limiting negative excursions.

*English Electric Company.

†Transistor T parameters: r_e = emitter resistance. r_b = base resistance. α = current gain.

staircase waveform from an input train of pulses††. The circuit is given in Fig. 4, and its operation may be briefly described as follows: Suppose that a train of pulses of amplitude V_{in} is applied to the input terminals. Assuming both C_1 and C_2 are initially uncharged, then the negative-going edge of the first input pulse causes D_2 to conduct and C_1 and C_2 to be placed in series across the input. Both receive the same charge, but since C_1 is made much smaller than C_2 most of the voltage appears across C_1. The charge added to each is thus approximately $q = C_1V_{in}$.

On the positive (trailing) edge of the first pulse, the potential of point X rises; D_2 cuts off, isolating C_2 from the input, and D_1 conducts, discharging C_1. Thus, at the end of the first pulse C_1 is once more without charge, but C_2 will have a potential difference across it of approximately $(C_1/C_2)V_{in}$. Thus D_2 is back-biased by this amount. It follows that on the next pulse D_2 will not conduct until the potential of the point X has fallen by $(C_1/C_2)V_{in}$. The voltage shared between C_1 and C_2 this time is thus slightly less, so that not quite so much charge is added to C_2 as on the first pulse. As the upper plate of C_2 becomes more negative on succeeding pulses, the input has to move farther and farther before D_2 conducts, and smaller and smaller amounts of charge are added to C_2; in fact, the envelope of the staircase waveform across C_2 is exponential.

Replacing D_1 by a transistor as in Fig. 5 makes the staircase linear. The action on the leading edge of the first pulse is the same as with the diode pump. On the positive trailing edge, the transistor conducts and behaves as an emitter follower which maintains point X at nearly the same potential as Y throughout the discharge of C_1. Thus on the arrival of the next pulse, D_2 has virtually no reverse bias and the whole input voltage is used to charge C_1 and C_2. The same argument applies whatever the potential across

††For example see "The Diode Pump Integrator," by J. B. Earnshaw. *Electronic Engineering*, January, 1956.

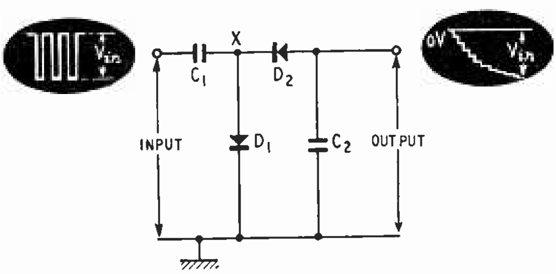


Fig. 4. Diode pump circuit

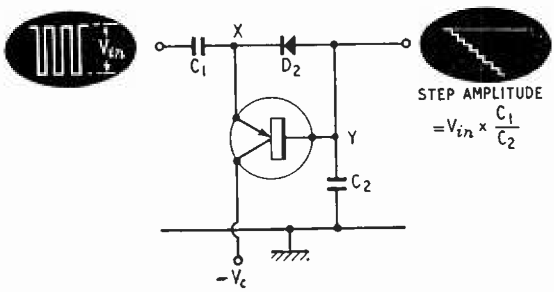
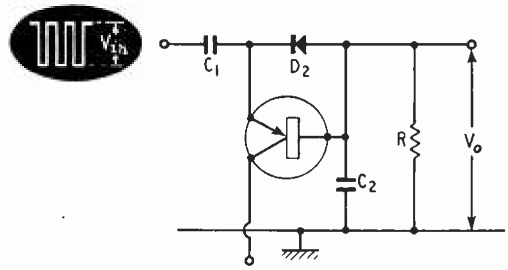
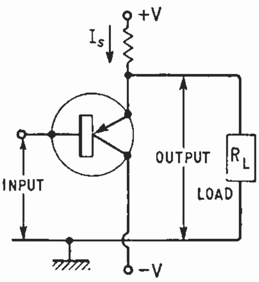


Fig. 5. Transistor pump circuit.



Above: Fig. 6. Simple linear frequency-voltage converter.



Right: Fig. 7. Emitter follower circuit.

C_2, and hence the increment of potential is exactly the same for each input pulse. A linear staircase results, the output being limited to values less negative than the collector supply voltage V_c. This circuit will produce only negative-going outputs; the corresponding circuit for positive outputs would use an n-p-n transistor.

One application of this circuit is to generate a voltage proportional to the frequency of a pulse train. A resistor R is placed across C_2 as in Fig. 6. Each input pulse puts a charge $V_{in}C_1$ into C_2, so that the average current into C_2 is $NV_{in}C_1$, where N is the pulse repetition frequency. When the circuit is in equilibrium the current supplied into C_2 must equal the current flowing out through R, which is V_o/R; where V_o is the output voltage; thus $V_o/R = NV_{in}C_1$, or $V_o = NRV_{in}C_1$. The output voltage is thus proportional to pulse repetition frequency: note that it is independent of the mark/space ratio of the pulses, and of the value of C_2 (if $C_2 >> C_1$). There will be a ripple component on the output of magnitude $V_{in}(C_1/C_2)$ volts peak-to-peak. The effect of the leakage current I_{co} flowing in the base of the transistor is to shift the zero of the output by a voltage $I_{co}R$; the variable nature of I_{co} will limit the maximum permissible value of this term, and hence of R.

Emitter-Squared Follower.—The emitter follower, Fig. 7, is a much used circuit where low output impedance is required. It is an unsymmetrical circuit, for although it can draw a substantial current (limited only by the signal source impedance and transistor dissipation) from the load R_L, it can drive *into* the load no more than the standing current I_s. This feature is particularly unfortunate when the circuit has to supply current pulses at a small mark/space ratio: the stage has to be designed with a large standing current which is needed for only part of the time. The drain on the power supply may be reduced and lower power transistors employed if the "emitter-squared follower" is used.

A d.c.-coupled version of this circuit feeding a capacitive load is shown in Fig. 8. Transistors V_1

and V_2 are connected in series and a standing current I_s ($I_s = I_{e1} \simeq I_{c2}$ under static conditions) flows through them and through R_c, the collector load of V_2. The circuit adjusts itself so that the voltage drop $I_s R_c$ coupled via R_1 and R_2 holds the base of V_1 slightly below earth potential (where it must be if V_1 is conducting).

On negative inputs to the base of V_2 the maximum current which can be drawn from the load is limited by R_c since V_2 must not bottom, and (as in the emitter follower) by the signal source impedance. On positive inputs some of the current I_s is diverted from V_2 into the load, with the result that the potential of V_2 collector falls and the base of V_1 is driven negative. V_1 is thus turned harder on and can supply into the load a current many times the standing current I_s. The principal limitation of the emitter follower is thus avoided.

The peak current into the load occurs when V_2 is cut off. It can be shown (see appendix) that the ratio of standing current to peak current into the load is approximately $1 + \frac{R_c}{R_2 + R_c} \cdot \frac{1}{1-\alpha}$. Since this is greatest for a large value of R_c whereas the peak current drawn *from* the load is greatest when R_c is zero, the design involves a compromise.

The variation with temperature of the working point of V_1 can be found by a simple approximate calculation as indicated in the appendix.

The base potential of V_2 must be chosen to allow adequate signal voltage excursions on the emitter and collector of V_2. It does not affect the standing current provided that there is no resistive load.

A circuit of this type has been used with great success as the output stage of an electronic integrator. It replaced an existing circuit using several tran-

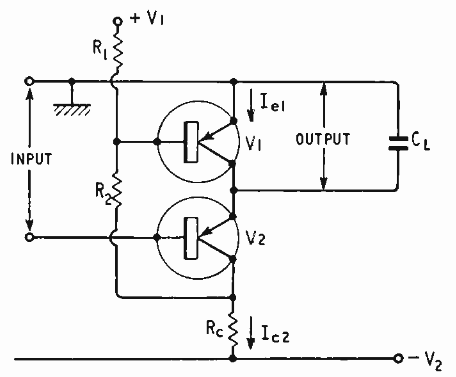


Fig. 8. Emitter-squared follower, d.c. coupled. Under static conditions $I_{c2} \simeq I_{e1}$.

sistors in parallel and drawing a relatively enormous current from the power supplies. Note that with this version of the circuit the power supplies must be reasonably stable, as the standing current depends rather critically on the supply voltages (see appendix).

Transistor Gating Circuit.—A transistor can be used as a simple and effective switch. Let us consider how this is done. If we connect up a transistor as in Fig. 9 we can define its emitter current I_e to be almost constant at V_1/R. The collector current I_c will be equal to $\alpha I_e + I_{co}$ and the base current I_c is thus $(1-\alpha)I_e - I_{co}$.

Reducing the magnitude of the collector voltage V_2 has little effect on I_c until the voltage between emitter and collector has fallen to a few millivolts; if further reduction is made in V_2 then I_c does begin to fall and the transistor is said to be bottomed. Since I_e is maintained constant the base current must increase, i.e., $I_b > (1-\alpha)\ I_e - I_{co}$.

This relationship is very important, because if we design any transistor circuit so that this inequality exists we know that the transistor is bottomed and hence that the voltage between emitter and collector is a few millivolts only.

Another important fact is that a transistor may be used back-to-front, that is, with the nominal emitter being used as a collector, and the collector as an emitter. Once again the voltage between emitter and collector is very small when the transistor is bottomed. The criterion for this is $I_b > (1-\alpha_r)I_e - I_{co}$ where α_r is the current gain of the transistor used back-to-front. Whereas α is typically 49/50, α_r may be as low as 2/3, so that more base current is needed to bottom the transistor in this case. Experience shows that adequate bottoming always occurs in the OC71 transistor when $I_b = 1 + I_e$ (I_b and I_e in mA). This will now be termed the bottoming criterion.

We can now see how the transistor can be used as a gate. In Fig. 10, I_b is made large enough to bottom the transistor so that point X, the emitter, will be almost at earth (collector) potential. In Fig. 11, X is again at earth potential although the transistor is operated back-to-front with current flowing from nominal collector to nominal emitter. Point X is even at earth potential in Fig. 12, where I_b has been made so large that I_c has reversed, although our previous argument does not help us since there are now in fact two emitters. Experiment shows, though, that as V_1 is reduced there is a

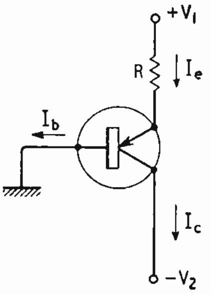


Fig. 9. Transistor with defined emitter current.

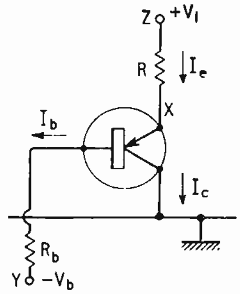


Fig. 10. Bottomed transistor, normal current flow.

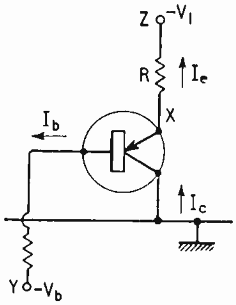


Fig. 11. Bottomed transistor, reversed current flow

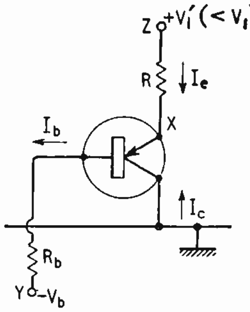


Fig. 12. As Fig. 10, but I_b is so large that I_c is reversed.

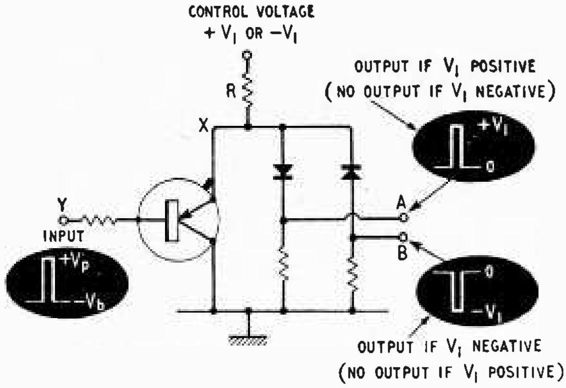


Fig. 13. Pulse routing equipment.

perfectly smooth transition from the Fig. 10 condition to the Fig. 12 condition and, when V_1 changes sign, to the Fig. 11 condition.

Point X is therefore always at earth potential when the bottoming criterion is satisfied. Since both emitter and collector are at earth potential either, or both, can be made to act as an emitter by taking the base a few tenths of a volt below earth. Thus whatever the sign or magnitude of V_1 the base is just below earth potential and the base current is

$$I_b \simeq V_b/R_b.$$

Now for the open condition of the gate. If Point Y (Figs. 10, 11, 12) is taken from $-V_b$ to a value greater than V_1, both emitter and collector are cut off and point X takes up the potential V_1. (This is not exact since the reverse emitter leakage current I_{e1}‡ produces a drop $I_{e1}R$ across R; this incidentally sets an upper limit to R at any particular operating temperature, since I_{e1} like I_{co} varies rapidly with change of temperature. Typically $I_{e1} \simeq \frac{1}{8} I_{co}$.)

The action of the circuit is thus either to transmit the voltage V_1 from point Z to point X, or to short-circuit X to earth, depending on the potential at Y.

The transistor gate is a most versatile circuit; one rather unusual application is a two-way pulse routing circuit shown in Fig. 13.

Point Y is held normally at $-V_b$ so that the transistor its bottomed. Point X and both outputs are hence at earth potential. Input pulses are applied at Y and momentarily raise it to $+V_p$, where $+V_p > +V_1$. The transistor is thus cut off and X, for the duration of the pulse, assumes a potential approximately $+V_1$ or $-V_1$. If this is positive, an output appears at A, if negative, at B. The input pulse thus produces a pulse at A or B depending on the sign of the control voltage V_1.

A great virtue of this circuit is that since X is always within a few millivolts of earth when the transistor is bottomed, there is negligible change of potential there when V_1 changes sign. There is no risk therefore of step changes in the control potential waveform appearing at the output and being mistaken for genuine output pulses.

‡ Emitter leakage current when collector also back-biased.

APPENDIX

(Refer to Fig. 8)

Static Conditions

When there is no load current $I_{e1} \simeq I_{c2} = I_s$ (the standing current) .... (1)

Since V_1 is conducting the junction of R_1 and R_2 is approximately at earth potential.

$$\text{Hence current in } R_1 = \frac{V_1}{R_1} \quad \ldots \quad (2)$$

$$\text{and in } R_2 = \frac{V_2 - I_{c2} R_c}{R_2 + R_c} \quad \ldots \quad (3)$$

Now base current in $V_1 \simeq (1-\alpha) I_{e1} - I_{co}$ .. (4)

and since the difference between currents in R_1 and R_2 equals the base current of V_1:

$$\frac{V_2 - I_{c2} R_c}{R_2 + R_c} - \frac{V_1}{R_1} = (1-\alpha) I_{e1} - I_{co} \quad \ldots \quad (5)$$

and writing from (1) $I_{c2} = I_{e1} = I_s$

$$I_s \left[(1-\alpha) + \frac{R_c}{R_2 + R_c} \right] = \frac{V_2}{R_2 + R_c} = \frac{V_1}{R_1} + I_{co} \quad (6)$$

Dynamic Conditions

The maximum current output occurs when the whole of I_{e1} is diverted into the load, i.e.. when $I_{c2} = 0$. If under these conditions we write $I_{e1} = I_{pk}$ we have that: base current of $V_1 \simeq (1-\alpha) I_{pk} - I_{co}$

and repeating the step that gave us eqn. (5) (remembering $I_{c2} = 0$)

$$\frac{V_2}{R_2 + R_c} - \frac{V_1}{R_1} = (1-\alpha) I_{pk} - I_{co} \quad \ldots \quad (7)$$

$$\text{or} \quad I_{pk}(1-\alpha) = \frac{V_2}{R_2 + R_c} - \frac{V_1}{R_1} + I_{co} \quad (8)$$

Comparing (6) and (8), we obtain for the ratio of peak to standing current

$$\frac{I_{pk}}{I_s} = 1 + \frac{R_c}{R_2 + R_c} \cdot \frac{1}{1-\alpha} \quad \ldots \quad (9)$$

Eqns. (6) and (8) give the designer the necessary information about the variation of I_s and I_{pk} with I_{co}, and hence their variation with temperature.

International Instrument Show

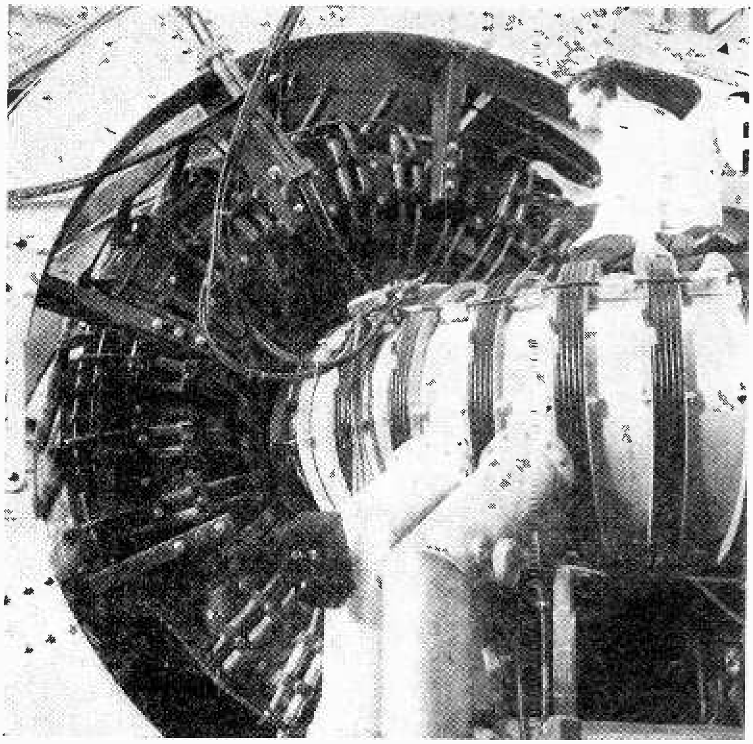
EQUIPMENT from 66 manufacturers in ten countries (see list below) is being exhibited at the 4th International Instrument Show to be held at Caxton Hall, Westminster, London, S.W.1, from March 24th to 29th. It will be opened each day at 10.30 and close at 6.30 except on Wednesday, 26th (9.0) and Saturday, 29th (12 noon).

In the past invitations have been sent to those who visited the previous year's show, but the organizers, B & K Laboratories, say this is no longer practicable because of the increased attendance last year. Applications for tickets should be made to the organizers at 57, Union Street, London, S.E.1 (Tel.: Hop 4567).

Austria: Ludwig Seibold.
Denmark: Bruel & Kjaer, Danbridge A/S, Disa Elektronik.
France: C. G. R., Jobin et Yvon.
W. Germany: Belzer-Werk, Dynacord, Deutsche Elektronik, Freiseke & Hoepfner. Hackethal, Intermetall, Rohde & Schwarz, Geo. Spinner, Wissenschaftlich Technische-Werkstatten.
Holland: Peekel Labs.
Italy: Lares S.R.L.
Sweden: Magnetic A.B.. Sivers Lab.
Switzerland: Metrohm A.G., Muller-Barbieri, Vibrometer Inc.
U.K.: Advance Components, G. & E. Bradley, Racal, Union Radio Co.
U.S.A.: Advance Electronics Inc., Allen Bradley Co., Ampex Corp., Applied Physics Corp., Applied Science Corp., Audio Devices Inc., Bendix Aviation Corp. Brush Electronics Corp., Cascade Research Corp., DeMornay Bonardi, Electric Eye Equipment Co., Electrical Industries, Electronic Speciality Co., Electro-Measurements, Inc., Electronic Research Associates, El-Tronics Inc., General Precision Lab., Gertsch Products Inc., The Heath Co., Huggins Labs., International Rectifier Corp., Kay Electric Co., Krohn-Hite Instrument Co., MB Mfg. Co., Narda Corp., Neu-tronics Research Co., Norden Ketay, Northam Electronics, Nuclear-Chicago, Panoramic Radio Products, Polarad Electronics Corp., Polytechnic R & D Corp., Raytheon Mfg. Co., S.W. Industrial Electronics, Sperry Gyroscope Co., Sprague Electric Corp., Stoddart Aircraft Radio, Tape Cable Corp., Varian Associates, Vectron Inc.

Controlled Thermonuclear Power

RECENT RESULTS OF RESEARCH ON HIGH-TEMPERATURE PLASMAS



View of ZETA showing half of the spectacle-shaped transformer primary through which the aluminium ring containing the deuterium gas is threaded. The spaced stabilizing field coils round the ring are also visible.

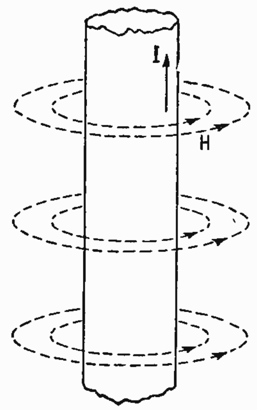
WHEN energy is released in a nuclear reaction, the total mass of the original reacting particles is more than the total mass of the products, the difference being equivalent to the energy produced. By collating data on the masses of nuclei, it can thus be shown that there are two types of nuclear reaction which release energy. One of these is the fission or splitting of nuclei of large atomic weight into two lighter nuclei, as used in atomic bombs or ordinary atomic piles. The other, as used in the hydrogen bomb, is the joining or fusion of nuclei of small atomic weight into heavier nuclei.

Fusion reactions have long been reproducible in the laboratory by the ordinary methods of nuclear bombardment. However, for obtaining an overall energy gain this method is quite inadequate, because nearly all the energy of the bombarding particles is lost in ionizing the target atoms. These losses could be avoided by using two colliding ionized beams; but in this case the highest particle densities which can be achieved are still far too low to give a usable release of power per unit volume.

Thermonuclear Reaction Conditions.—Sufficiently high particle densities can be readily obtained in a self-reacting system. The obvious way then to make the energy of the particles high enough for fusion reactions to occur, is to heat up the system until this energy is provided by the thermal (kinetic) energy of the particles, the reactions then being said to be thermonuclear. At the temperatures thus necessary, ionization is nearly complete, such a completely ionized gas being called a plasma. The required temperatures are in fact so high, at least tens of millions of degrees centigrade, that in practice only those reactions needing the lowest temperatures need be considered. The energy of the reacting nuclei can be smallest when the repulsion between their charges which must be overcome before any reaction can occur is also smallest. Thus the reactions to be considered are those between nuclei of low atomic number. The easiest reactions to bring about are then found to be those involving the heavy isotopes of hydrogen, i.e., deuterium and tritium. The temperature required to produce a reaction between deuterium and tritium is about one half of that required for deuterium alone; but this advantage is offset by the scarcity of tritium.

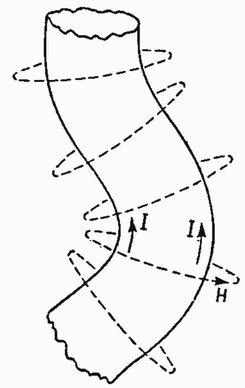
The rate at which individual thermonuclear reactions occur increases as the temperature is increased, so that the total thermonuclear energy produced also increases. Energy is radiated from plasmas producing thermonuclear energy mainly in the form of bremsstrahlung, i.e., X-rays produced when free electrons are deflected by positive ions. This radiated energy also increases with temperature, but at a slower rate than the total thermonuclear energy produced. Thus, at a sufficiently high temperature (at least 5×10^7 degrees centigrade in the reactions of interest) the thermonuclear energy produced will equal the energy radiated. Assuming no energy is conducted away this then is the lowest temperature at which a self-sustaining reaction is possible. At such temperatures usable amounts of energy per unit volume are released at particle densities corresponding to quite low pressures of the order of 0.1 mm of mercury or less. These pressures are, however, greater than those in ordinary gas discharges.

Reasons for Confining the Gas.—The energy conducted away is proportional to the surface area,



Above: Fig. 1. Pinch effect. The field H forces inwards currents such as I in the outer part of the discharge.

Below: Fig. 2. Kink instability. The field is greater on the inside of the bend than on the outside, so that the dissimilar forces on the currents I tend to make the bend larger.



whereas the thermonuclear energy produced is proportional to the volume. Thus the conduction can be relatively reduced by increasing the size of the system. At the pressures and temperatures we have discussed, however, it will still far exceed the radiated energy for any practical size of system. Thus, to operate at the lowest possible temperature, conduction must be prevented by separating the reacting gas from the walls of the container by means of a suitable force. Moreover, at the low plasma densities used, the average distance of about 50,000 km between collisions is so long, that unless such a containing force is used, the particles will escape from the reacting region. This long distance between collisions also means a long average time interval (about ten seconds) between energy-producing collisions. Thus to ensure that the fraction of nuclei which take part in thermonuclear reactions is large enough to give a net energy gain, the gas must be confined for a time of the order of a second.

Fruitless Confinement Methods.—Gravitational attraction is only possible as a means of confinement in systems of stellar mass. However, at these temperatures and densities the ionized gas is about one hundred times as good a conductor as copper, and this suggests that electric or magnetic fields could be used to confine it. Electric fields cannot be used both for theoretical and practical reasons. Theoretically, Earnshaw's electrostatic theorem shows that no stable equilibrium position would be possible, and also, a confining field for the electrons would tend to disperse the positive ions. Practically, the fields required, of the order of 10^7 volts/cm, are much higher than the highest which can be produced.

Pinch Effect.—Confinement by means of magnetic fields is feasible. Fields of about 10^5 gauss are required, and these can be produced in the plasma volume by currents of the order of 10^7 amperes. The simplest way to produce a field in the right direction is to pass a current through the gas, when the direction of the field may be determined by the corkscrew rule. The force on currents flowing through the outer part of the discharge is then inwards (by Fleming's Left Hand Rule) as may be seen from Fig. 1, this being known as the pinch effect. By considering the discharge as being composed of a number of parallel currents, the pinch effect may also be regarded as being due to the attraction between parallel currents in the same direction; this attraction being caused by similar interaction with the magnetic fields produced by the currents. Such high currents, possibly together with adiabatic compression produced by the pinch effect or otherwise, will in any case have to be used to heat the gas sufficiently. Thus this method of confinement is both simple and convenient.

Unfortunately, the pinch is unstable, any small displacement at right angles to its length increasing until the plasma column is disrupted. This is because the magnetic field at the concave portion of such a kink is increased and that at the convex portion is decreased, as shown in Fig. 2. Thus the inwards attraction is increased at the concave portion and decreased at the convex, thus producing a net resultant force tending to increase the kink. The increase in the size of a kink is in fact extremely rapid, and the plasma column becomes disrupted in less than a few microseconds.

Avoiding Kink Instabilities.—Two methods of counteracting this instability have recently been reported. One of these is simply to use a metal conducting container for the gas. If the plasma then moves from a central position its magnetic field induces eddy currents in the container walls in such a direction that by Lenz' law their associated magnetic field produces a force on the plasma back towards its central position.

The other stabilizing method is to apply a magnetic field along the discharge. This field becomes almost completely trapped in the discharge as it contracts. This is because, owing to the very high conductivity of the plasma, any movement of the field through it would induce such high currents that their associated fields would cancel out the field movement through the plasma. Similar effects are observed with superconductors. Any kinking of the discharge then distorts the trapped field so that the kinking is opposed, as would also happen if the field lines were replaced by their usual stretched elastic band analogues.

A consideration of the paths of the individual charged particles also shows how a magnetic field inhibits motion at right angles to it. In this case, the paths become circles with radii inversely proportional to the field strength. Because of this coiling up of the motion of the particles, the mean distance between collisions for movement at right angles to the field becomes roughly equal to the radius of the circular motion. The mean distance between collisions may thus be considerably decreased, this making the rate of diffusion much less.

No confinement of the plasma length is provided by the pinch effect. The obvious way to avoid losses at its ends is then to close it upon itself to form a ring. The heating or pinching current in the discharge must then be obtained by induction, such as simply by making the whole ring the single-turn secondary of a pulse transformer. The high currents required can be produced by discharging a condenser through the primary. The metal container must be subdivided into a number of insulated sections to avoid short circuiting the current input to the discharge.

Most of the published experiments have followed this general line of attack, though other methods are also being developed in America. In some cases linear discharges have been used, and also stabilization solely by means of a longitudinal field. Temperatures of several million degrees centigrade have been generally obtained.

ZETA.—The longest containment time which has been achieved is 5msec in ZETA at Harwell. Here temperatures up to 5×10^6 degrees centigrade have been reached in deuterium gas at pressures of from 10^{-4} to 10^{-3}mm of mercury. The containment time and temperature are at present only limited by the available power input which it is hoped to increase shortly.

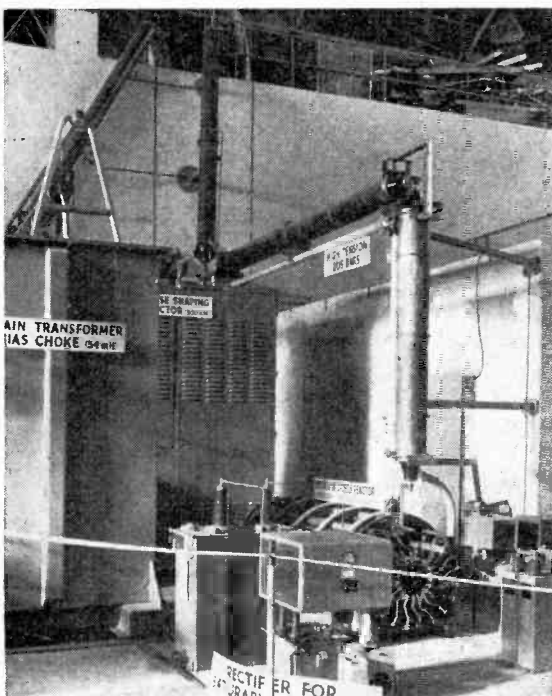
ZETA uses a ring discharge container of one metre bore and three metres mean diameter. This threads the two halves of the spectacle-shaped transformer primary through which 1600μF at 25kV are discharged to give up to 2×10^5 amperes in the deuterium gas "secondary." This gas is initially weakly ionized by a discharge at 4 Mc/s using about 1kW of power. The stabilizing field used is quite small, about 200 gauss, though this is rather less than that used in other experiments. It is produced by coils wound round the ring. The container is made of one inch thick aluminium, subdivided into 48 insulated sections.

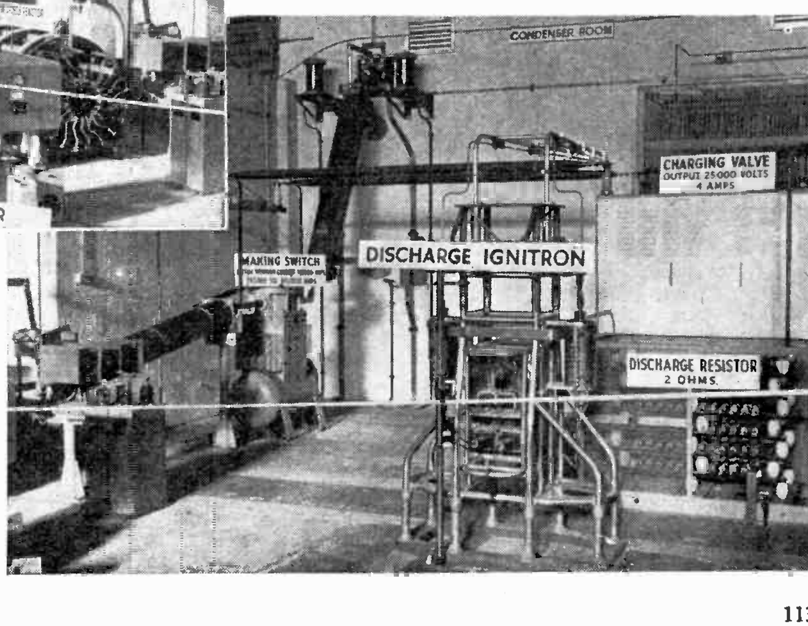
Plasma Diagnostics.—Owing to the use of a mixture of ions of opposite charges and different masses (electrons and nuclei), in the simultaneous presence of magnetic and electric fields in various directions, under conditions where radiative and nuclear effects are important, and with the possibility of oscillations, transients and turbulences, very complicated processes can occur for which the theory is often only approximate.

A wide variety of measuring techniques are therefore used. Taking non-electronic methods first, there are the spectroscopic techniques used in studying the stars modified to deal with the higher temperatures. An important example of these is, of course, the measurement of temperature from the broadening of line spectra produced by the Doppler effect for thermal motion. Densities can also be measured in this way, and electric and magnetic fields (Stark and Zeeman effects) and overall motion may also produce line broadening. Impurities must be used, as the deuterium, being almost completely ionized, produces little fixed frequency radiation. Conversely, the presence and amount of impurities may be detected from the spectral lines they produce. This can give information about any erosion of the container walls due to bombardment, vaporization or arcing. Impurities are undesirable because the radiation increases rapidly for other nuclei of higher atomic number. The temperature can also be measured from the noise produced at millimetre wavelengths.

High-speed photography of the discharge details can be carried out through suitable windows. Measurement of the total light output is also valuable.

Among nuclear measurements, the observation of the neutrons which are emitted from fusion





Part of the power supply for ZETA showing from left to right, above, matching choke, pulse shaping reactor, saturable reactor initial current limiter, and below, discharge switch, alternative discharge ignitron and resistor, and charge current limiting valve; all connected to the high voltage coaxial cable. The condenser room is at the rear.

reactions can give information on the temperature, density of spatial distribution of the plasma. Such neutrons should be detectable at much lower temperatures than those necessary to give a power gain from thermonuclear reactions. Unfortunately, various types of electromagnetic disturbance can also accelerate the deuterons to produce neutrons, and it is difficult to distinguish with certainty between these two effects. High energy X-rays are also produced in the plasma.

Electric and Magnetic Measurements.—A simple measurement of voltage and current in the pinch can be used to determine its radius. Neglecting resistive effects we have $V = d/dt\,(LI) = L\,dI/dt + I\,dL/dt$, where L is the inductance and t the time. Inserting measured values for V, I and dI/dt then gives an equation which can be solved for L as a function of time. L is also a known function of the pinch dimensions.

Magnetic fields can be measured from the currents they induce in coils both in and outside the discharge. When such fields are trapped in the plasma this measurement also determines its motion. Electric fields and ionization may be measured from the current between two electrodes at different potentials inserted in the gas (Langmuir probe). The use of probes in the plasma is limited by the need to avoid disturbances and losses.

By observing the transmission or reflection of millimetre waves in the plasma, data on its refractive index may be obtained. Since this is equal to $[1-8.1 \times 10^{7} (n/f^2)]^{1/2}$ where n is the number of electrons per cubic centimetre and f the frequency in c/s, this also gives a measure of the electron density.

Energy Extraction.—Ideas on this are of course entirely theoretical at present. The obvious method is to extract heat from the discharge as it eventually reaches the container walls.

The emitted neutrons could possibly be used to control or initiate a modified fission reactor. Their energy could be recovered by absorbing them in lithium six. The resulting nuclear reaction, besides giving off energy, also produces tritium which could be used in the discharge.

An exciting possibility is to use the magnetic field arising from the plasma to induce current directly in an external circuit.

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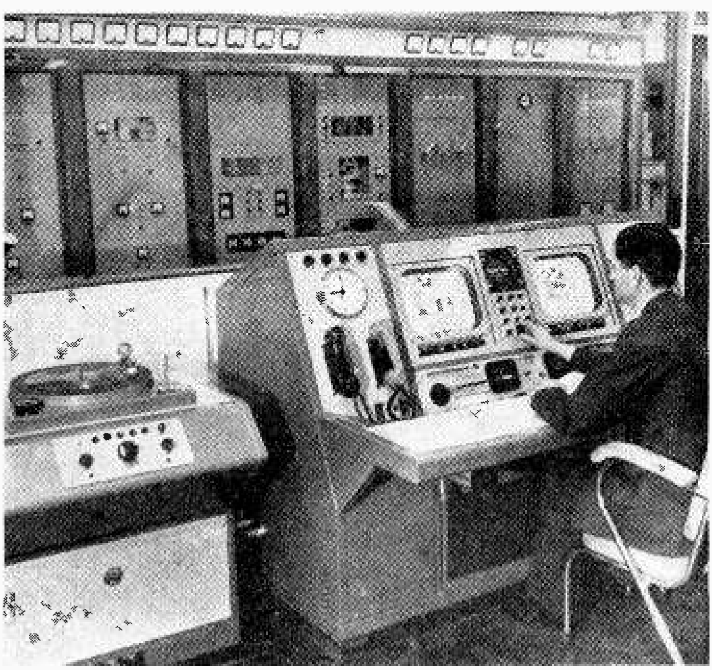
I.T.A. ST. HILARY STATION: DETAILS OF THE PYE TRANSMITTER

PROGRAMME transmissions from the new I.T.A. station at St. Hilary, near Cardiff, began on January 14th. Only three months had been needed for the installation and testing of the Pye transmitting equipment.



Console control equipment for the I.T.A. St. Hilary station. Also shown facing the operator is the 20-kW vision transmitter.

The 20-kW (200 kW e.r.p.) vision and 5-kW sound transmitters have been given a similar design, except for their final output stages, to reduce the number of spare valves and components required. Each consists of a crystal drive, stable in frequency to better than 1 part in 10^7, whose 3-watt output is applied to a frequency multiplying unit to give the carrier frequency. The 30-watt output from this unit is amplified to levels of 500 watts and 5kW in the next two stages.

In the vision transmitter the picture modulation is applied to the grids of the 5-kW amplifier valves. The modulated signal output drives the cathodes of the final vision output amplifier, which uses two 4W,20000A tetrodes in a grounded-grid double-cavity resonant circuit. The sound transmitter is anode and screen modulated in the final output stage which uses only a single 4W,20000A valve.

Coaxial cable is used throughout the additional G.P.O. vision links which integrate the new station into the whole I.T.A. network. In most cases, after double frequency changing, signals are transmitted on a carrier frequency of 1.056 Mc/s in the band 0.5 to 4.0 Mc/s.

WAVE MECHANICS

Different Laws for a Small-Scale Universe

By "CATHODE RAY"

LAST month we considered the two basic ingredients of the universe: mass and energy. They seem so obviously different in kind—one being the most material thing about matter, and the other somewhat abstract—that it was surprising to find that each can be converted into the other at a fixed rate of exchange. Still, this didn't necessarily mean that they had much in common, any more than pound notes have much in common with 18 days' tour of the Tyrol, apart from being exchangeable at a certain rate.

It had been known for a long time that matter was made up of atoms, which come in certain fixed sizes; and even though atoms were later found to be made of electrons, protons and neutrons, these were particles of certain definite sizes. Energy, on the other hand, seemed quite different—something that could be handed out in any quantity, large or small. It could be radiated from place to place as light, heat, radio, X-rays, etc., and although as great a scientist as Newton had held some queer notion about light consisting of streams of particles, that was hundreds of years ago and had long since been thrown overboard because of the overwhelming evidence that all these kinds of radiation were electromagnetic waves, which of course streamed forth continuously and were capable of having any amplitude.

Packets of Energy

But with the dawning of the twentieth century, evidence was accumulating which just didn't fit these apparently soundly established principles. So Planck put forward his quantum theory that energy is not radiated as a continuous flow but in "packets" or quanta, the sizes of which are directly proportional to the frequency of the radiation and are not related at all to its intensity. This theory seemed (to say the least) unlikely, but has become more and more firmly established as it has been found to agree with more and more experimental facts. You may remember that one of the things it was invented to explain was that high-frequency radiation, however small in amount, is able to ring the bell of atomic "Try Your Strength" machines, where unlimited quantities of low-frequency radiation completely fail.

The thing is expressed a little more scientifically in Planck's equation which we noted last month:

$$E = hf$$

in which h is Planck's constant (6.6×10^{-34} joules per c/s), and E is the amount of energy in each quantum of radiation at frequency f c/s. Yellow light has a frequency of about 5×10^{14} c/s, so its energy is radiated in quanta of $6.6 \times 10^{-34} \times 5 \times 10^{14} = 3.3 \times 10^{-19}$ joules. Now a joule is a watt-second; that is to say, the amount of energy equal to a power of one watt working for one second. It can also be called a volt-amp-second, or (since a current of one amp flowing for one second carries a charge of one coulomb) a volt-coulomb. Since the energy of a single quantum of even high-frequency radiation is very small, it is more conveniently expressed in much smaller units. An electron carries a charge of only 1.6×10^{-19} coulombs, so a volt-electron or electron-volt (eV) is a convenient unit for small amounts of energy. Our quantum of yellow light, for instance, is $3.3 \times 10^{-19} / (1.6 \times 10^{-19}) = 2$eV. This is equal to the amount of kinetic energy acquired by an electron in "falling" through a difference of potential of 2V, say between cathode and anode of a diode. It is analogous to the 2 ft-lbs of k.e. acquired by a 1 lb weight in falling 2 ft.

Contrasts in Quanta

In the same simple way we can calculate that each quantum of energy emitted from the Crystal Palace television station with all the majesty of its 200 kW e.r.p. is rather less than one fifth of one electron-*micro*volt—like a grain of grit to the dog-carrying sputnik radiated by the dimmest candle. At the other extreme come quanta of 10,000 eV upwards from X-rays, and of many millions of eV in cosmic rays. It is just as well that they are so thin on the ground!

The difficulty is to reconcile this sort of thing with all the evidence to show that radiation consists of waves. As regards radio, no one seems even to attempt to do so. The wave concept still reigns supreme. The reason presumably is that the radio-wave quanta are so insignificant individually and so numerous that there is no more inducement to consider them than there is to take account of each separate molecule when pouring out the tea. One is more likely to notice that by blowing on tea one can form it into the most convincing-looking miniature waves! X-ray quanta, on the other hand, are like the lumps of sugar—much fewer, but each capable of creating quite a noticeable splash. So it is usual to consider this high-frequency radiation as quanta rather than waves.

To introduce the subject of loudness in last November's issue, I drew what seems to have been accepted without question as a reasonable representation of an air wave by varying pencil-shading along a strip of paper. Although the general impression at a glance was that the depth of shading varied continuously in a wavelike manner, looking at it through a magnifying glass would reveal that this impression was produced by the varying density of grains of graphite. One could put it this way: that the intensity of air-wave pressure at any point was represented by the probability of finding a grain of graphite at that point. The physicists' statement that radiation consists of "waves of probability" may sound very baffling until we realize that the same thing applies to this pencilled picture of a wave.

So the picture is a help. But if we're not careful we shall be misled by it. If we follow it up too closely we'll visualize a radiator sending out a cloud of photons (as these quantum-sized packets of energy are called) gradually increasing in density as the positive peak of what we otherwise describe as the wave is reached—and then we will be stuck to describe what happens during the negative half-cycle, for there are no negative photons. Even if there were they wouldn't correctly represent a negative half-cycle. The mistake (for which I with my pencilled airwave analogy am chiefly to blame) is in supposing that the density of photons represents the *instantaneous* value of the wave, whereas it represents its power intensity or mean square value. The frequency of the radiation is not conveyed by the photon density being broken up into a wavelike distribution, but by the size of their quanta. If each one is about 2eV and some of them reach our eyes we say "Ha! there is a yellow light!" (or words to that effect) and, performing optical tests on them, we find they behave in many respects as if they were waves of frequency 5×10^{14} c/s (=500 MMc/s) and length 6×10^{-5} cm. That being so, it is allowable and convenient to make use of wave mathematics so far as applicable. At the low-frequency end—and that includes all our radio, even microwaves—it is applicable practically all the way. They are therefore commonly called waves, even by people who know differently.

Travelling Through Space

While this makes it hard for us to accept the particle idea, we must admit that it clears up at least one major difficulty—how the supposed waves cross empty space, since it has been demonstrated that there isn't even an ether to carry them. Particles, on the other hand, travel most easily through space that is completely empty, which is also a feature of radio "waves" and light.

Almost as soon as people had been driven to the conclusion that these "waves" of radiation were, in spite of all appearances to the contrary, streams of particles, another line of research was demonstrating that streams of particles (to wit, electrons) behaved in some respects as waves! Although such a thing is singularly difficult to visualize, there is a certain rough logic in it. The rigid distinction between mass and energy, each with its separate Law of Conservation, had already been broken down, yielding a single Law of Conservation of Mass-cum-Energy. So it is appropriate that the rigid distinction between waves and particles should break down into something which seems to be both at once. But just as the queer tricks that things get up to in Einstein's relativity are only significant at extremely high speeds, the particle aspect of radiation is only significant at very high frequencies and the wave aspect of particles is only significant in very small sizes. So although theoretically the traditional "hail of bullets" from the ruthless foe behaves to some extent like a beam of light, the extent is negligible. When one gets down to the electron size, however, the situation is quite different. So different that the behaviour of electrons cannot be explained or described at all fully on the assumption that they are just very small particles, but only on the assumption of a strongly wave-like nature.

The working out of this theory, which has been very successful in elucidating the behaviour of electrons, especially as components of atoms, is known as wave mechanics; and the worker-out-in-chief was Schrödinger. The name "wave mechanics" is likely to have a discouraging sound, bringing together as it does two ideas which do not seem to make much sense in combination. But then in atomic physics one must be prepared to abandon so-called common sense, which is no more than the really rather stupid mentality of the Jovian giant who assumed that the bricks of which earth houses are built are themselves tiny houses. It is equally stupid of us to expect that the ultimate "bricks" of the material objects we can see are similar in nature only smaller. It is rather presumptuous to expect to be able to understand their real nature at all. But wave mechanics has enabled people to get a much better insight than the "tiny billiards ball" ideas of the past.

This is where we take up again the unsolved puzzle of last month—the atom, which we know consists of a number of electrons around a nucleus. Because these are oppositely charged, there is an electric force tending to draw the electrons towards the nucleus. This sort of situation is familiar to us on our earth, where there is a gravitational force tending to draw all other bodies to it. We know that the electrons do not in fact ever fall right down to the nucleus, so something must keep them up. Their obvious counterpart would seem to be the moon, which stays up by revolving around the earth at a suitable rate. But whereas a moon's orbit could be at any radius, provided the rate were suitable, it is known that there are only a limited number of possible "orbits" for electrons. And anyway, why don't any ever fall? Even sputniks do so in time, and millions of meteors fall to the earth—or at least its atmosphere—every day.

Calculated Probabilities

The answer is given by wave mechanics. Unfortunately it is essentially mathematical, so it is not at all easy to visualize even in roughest outline, but it goes something like this:

The ordinary laws of mechanics, which apply very well to moons and sputniks around the earth, prove inadequate when the scale of the system is as small as electrons around a nucleus. In both systems there are satellites moving in a field of force; the moon moves in a gravitational field and the electron in an electric field. Because of the small scale of the electron, the equations of mechanics relating to its motion around the nucleus are modified in a way closely similar to the equations of the wave theory of light relating to a beam in a medium of varying refractive index (such as the air above a hot radiator, which bends the light rays so that the air is seen to shimmer). We have already noted that the intensity of light anywhere means the probability of finding a photon there, but that it can nevertheless for convenience be reckoned as the strength of an imaginary ether wave vibration. Correspondingly in wave mechanics, the probability of finding a particle anywhere can be reckoned in terms of imaginary wave vibrations of another kind. It turns out that this modification makes no significant difference unless the particles are very small; when they are as small as electrons the particle-likeness gives place very considerably to wave-likeness.

Even if I were capable of expounding the mathematics of wave mechanics, this would not be the place to do it. There are plenty of books. But in passing I suspect that there is quite a close analogy between the nature of electrons and (a) the behaviour of radio signals in the ionosphere, and (b) the distortion of pulses in line transmission, discussed by Thomas Roddam in last December's issue.

The above summary of wave mechanics is probably as clear as mud, but I hope that one shining pearl can be salved from it—the bit about the probability of finding an electron. For lack of anything better we have been talking in terms of the now outmoded electron *orbits* around the atomic nucleus. There is never any chill feeling of doubt about the precise position of the moon at any moment; if we do not personally know, we are quite sure the astronomers do. Even sputniks can be plotted with considerable accuracy. But to extend this idea of precise position to bodies as small as electrons has been found to be illusory. The best we can do is write an equation or plot a curve showing the relative probability of a body being at various points in space. With all except very small bodies the indication is a virtual certainty for one position and a negligible probability everywhere else. But an electron can only be pictured as a haze of probability around the nucleus. The simplest atom, of course, is a hydrogen atom, with only one electron; and Fig. 1 is a curve showing the probability against radius from the centre of the atom. This should not be taken to mean that the electron is actually at a certain constant radius which we don't happen to know exactly; it means that the electron is on the move all the time and at any given moment it could be anywhere, but that the chance of its being at any particular distance from the nucleus is proportional to the height of the curve in Fig. 1 at the point representing that distance. The curve shows that at distances greater than two hundred-millionths of a centimetre (=2 Ångström or 2Å) the chance is small.

As Fig. 1 shows, the most probable radius is 0.53Å. The interesting thing about this is that according to the older (orbit) theory, due to Bohr, the radius of the orbit nearest the nucleus (seat No. 1 in our atomic restaurant, or the lowest energy level) was 0.53Å.

Elusive Electron

This substitution of a probability haze for a clearly defined orbit seems to be a retrograde step, and one may well ask if it is really necessary. Why shouldn't mathematicians who are clever enough to think up such a system as wave mechanics be able to specify the precise movements of their satellite, like the astronomers can do standing on their heads? The answer comes, quite definitely and relentlessly, that neither in theory nor practice can anyone ever tell exactly where any electron (having a fixed energy) is. Accustomed as we are to scientists having the answer to really difficult questions at once and impossible ones at short notice, this unanimous ignorance concerning what one would have thought was routine stuff is astounding. It has at least been dignified by a special name—Heisenberg's Uncertainty Principle. Naturally we hasten to make all sorts of bright suggestions as to how an electron could be located, and the scientists explain with as much patience as they can that all these methods involve some sort of observation, and the observation is bound to affect the momentum (and hence the energy) or position or both, to an extent that is decisive when the thing observed is as small as an electron. One is apt to assume, for example, that just looking at a thing leaves the thing unaffected; but it is only because the thing is emitting quanta of energy that it is visible, and such emission alters the state of the emitter even before it reaches the eye of the observer.

But to get back to where we were with wave mechanics before that interruption. When the basic equation (the Schrödinger equation) is applied to the particular case of an electron in the field of force around its nucleus, the result is a general equation with only a limited number of physically possible solutions. The celebrated Ohm's-law equation, $I=E/R$, is an example of a general equation, in which theoretically E and R—and therefore I—can be absolutely any quantities. But if the only resistors in the world were identical carbon blocks and the

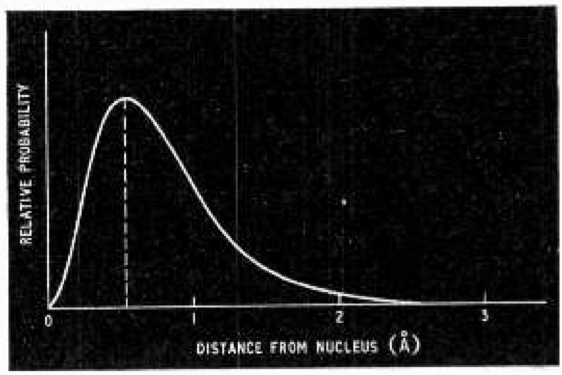


Fig 1. Relative probability of finding an electron at different distances from the centre of a hydrogen atom, when the electron is at its basic or lowest energy level.

only sources of e.m.f. were lead/acid cells, then the current I could in practice only have certain values, functions of whole numbers (the numbers of blocks and cells in series and parallel arrangements). And so it is with the Schrödinger equation applied to atoms. The total energy of an electron as part of an atom is made up of potential energy, which is less the nearer the nucleus it is (compare a weight at different heights above ground) and of kinetic energy, which is greater the nearer the nucleus it is, because it has to move faster. This increase in k.e. only half offsets the loss in p.e., so the total is less at short radii. The Schrödinger solutions correspond to certain isolated energy levels, each with its haze of probability differently spaced around the nucleus.

Because Fig. 1 applies to radii in any direction from the nucleus, the haze represented by it must be spherical in shape. That seems so natural that we may be surprised to learn that most of the other hazes, corresponding to higher energy levels, are not spherical but stick out sideways like the solid polar diagrams of directional aerials. Their forms are determined by the Schrödinger whole numbers. These come in sets of three, each set representing a possible electron haze or energy level. In each of these there can actually be two electrons. But this is not really a breach of the Pauli Exclusion Principle (the dignified name for the no-petting rule which decrees that only one person shall occupy any restaurant seat at any one time). Part of the k.e. of the atomic electrons is due to their spinning around themselves as well as around the nucleus, as the earth spins on its axis while revolving around the sun. And because the two electrons that both answer to the same three-figure code specification spin in opposite directions, a fourth figure can be added to the code to indicate direction of spin. So although the seats are in pairs, each seat (distinguished from all others in that restaurant by its own four-figure code) will take only one electron.

Coded Specification

The modified picture of an atom that emerges from wave mechanics thus consists as before of the nucleus surrounded by a certain number of electrons, depending on what the atom is an atom of, but instead of each electron being locatable in an orbit of definite radius it is marked by a haze, the density of which at any point represents the probability of its being there. Although this seems vague, the size, shape, position and density-pattern of the haze is quite precisely defined by a four-figure code sign. These code signs are confined to a quite moderate range of whole-number combinations, specifying the individual seats in any of our atomic restaurants. Every electron in an atom must occupy a separate seat (Pauli Exclusion Principle). The seats occur in groups, corresponding to the restaurant tables; those in a given group are distinguished by having the same first figure in their code signs. Most of them are divided into sub-groups, indicated by the second figure. Each seat is a certain energy level, beginning with No. 1 (code 1-0-0-a or b) nearest the nucleus with the lowest energy. An electron can be kicked up into a vacant higher-energy seat, if a sufficient quantum of energy to do it comes in from somewhere. Such an electron tends, however, to drop back from this elevated position, and in so doing gives up a quantum of energy equal to the difference between the energy values of the two seats concerned.

Exchanges of this kind are constantly going on, and are of especial interest to readers of *Wireless World.* For instance, the atoms in the fluorescent screen of a TV tube are supplied with energy by the high-speed electrons shot at them from the gun; their own electrons are pushed thereby into higher energy levels, and quickly drop back again. The kind of atoms put there by the manufacturer were chosen by him so that the differences in energy levels were such that the frequencies of the radiation, as calculated by Planck's equation, are distributed broadly between 400 and 800 megamegacycles per second, these being the frequencies that make up white light.

This is only one of many examples of these electronic energy exchanges, which are the subject we have been pressing on towards all the time. Next month we go into more detail about how they happen and the results produced.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

The Clark Cell

I OPENED W.W. in some trepidation this morning, fearing to read that both "Free Grid" and "Diallist" had been asked to resign for stating that the e.m.f. of the Clark cell was 1.1 volts. Kaye and Laby, whose physical and chemical constants have supported my left elbow since 1919, say that it is 1.433 volts at 15°C.

As a very junior egghead I used to buy my bell-wire and cables in coils of 110 yards and I used to believe that if one put 110 volts in at one end, 100 volts came out at the other; not for long. Anyhow 110 volts made a nice "long" volt on the analogy of a "long" calorie.

Little Hadham, Herts. HUMPHREY DENHAM.

Tape Speeds

IN connection with the recent discussion of the tape speeds I would like to supply the following information.

The Deutsche Normenausschuss (DNA)—German Standards Committee—divides tape recording equipment into different "classes" according to the tape speed. Its standard, DIN 45 511*, distinguishes between five classes which correspond to the following speeds:

Class	76	38	19	9	5
Tape speed (cm/sec)	76.2	38.1	19.05	9.53	< 9.53
Tape speed (in/sec)	30	15	7.5	3.75	—

For class 5 the speeds of 9.53/2, 9.53/4, 9.53/8, etc., cm/sec are preferred. It can be seen that the class number immediately gives an indication of the tape speed. Without resorting to new units this classification seems to be a convenient way of describing a tape recording system. The same standard (DIN 45 511) also covers the electrical properties of the different classes, e.g., frequency response, input and output voltages and impedances, signal-to-noise ratio, etc.

P. E. BECKMANN,
University College of North Staffordshire.
Keele, Staffs.

* Published by Beuth Verlag, Cologne, Germany.

I WAS interested to see your editorial comment and Mr. Davies' letter concerning tape speeds in the February issue. It is indeed praiseworthy that an international basic speed should be agreed upon, and the round figure of 30 is convenient for us. It is unfortunate that fractions occur when it is divided by a factor (standardized as a multiple of 2) to give the slower speeds.

But why divide? For example, $1\frac{7}{8}$ could be written as 30/16, which is not only easy to write but shows the relation to the basic speed, and makes it very easy to calculate the playing time, since with 150 feet of tape the playing time in minutes is equal to the above-mentioned factor.

Example: Speed 30/16 in/sec, length 600ft.

Playing $\text{time}=16\times\frac{600}{150}=16\times4=64$ minutes.

I hope, if this or a similar notation is adopted, that the whole fraction is used, and not the factor alone, which is inversely proportional to speed.

Birmingham, 13. D. L. CLAY.

AS a very early wireless man I recall visiting Copenhagen in 1910 and meeting Dr. Poulsen, of arc fame. He demonstrated his Telegraphone to me and I always associate tape recording with this brilliant man. For your proposed unit Poulsen is probably too long, but "Teleg" might do. What about "Dane"?

London, W.4. H. ANTHONY HANKEY.

FOLLOWING "Free Grid's" remarks and Mr. H. Davies' letter in your January and February issues respectively, you invite suggestions for an appropriate name for the unit of tape speed. I would like to offer one.

Before doing so, may I comment on the suggested origin of the multiple of 11 prevailing in power-supply voltages and referred to by "Diallist" and "Free Grid." I have always understood, admittedly in a vague sort of way, that it was based on a tentative maximum regulation figure of 10 per cent. To be more explicit, if you generate at 110 V and assume a 10 per cent drop under the worst conditions, i.e., at the end of a long, not overloaded line, you would at least have a terminal voltage of 100 V, a nice round figure.

I, like Mr. Davies, do not know why 77 cm/sec precisely was adopted as the standard tape speed in Germany but again, in a rather nebulous fashion, I understood it was for the following sound reason. The German Magnetophon spool was designed to hold a 1,000-metre length of tape, a good all-round figure. At a speed of 77 cm/sec the playing time for a full reel is nearly 22 minutes; time for a 20-minute programme plus an 8 per cent margin.

I think it rather a pity that you should turn down "Free Grid's" suggestion of the Stille as a unit of tape speed. Its singular aptness is appreciated only when one grasps the significance of his proposal that 100 Stille should correspond to $1\frac{7}{8}$ in/sec. On this basis, one Stille would presumably be 0.01875 in/sec, a tape speed at which you could reasonably say that one Stille was a little stiller than two Stille. If, as I suspect, "Free Grid" intends the Stille to be used not as a factor but as an exponent like the decibel, i.e., tape speed $= 1\frac{7}{8} \times 2$ to the power $(-100 + \text{St.})$ in/sec, then one Stille would be a little stiller still.

Seriously, why not "Poulsen" as a suitable name for the unit since, if anyone is entitled to be called the father of magnetic recording, surely it is Valdamar Poulsen? B.S. 1991 already gives two meanings for P. Who are we to boggle at a third?

Slough, Bucks. H. G. M. SPRATT.

F.M. Discriminator Bandwidth

I WOULD like to point out that a further advantage of a wide-band discriminator, discussed by Dr. Phillips in the December 1957 issue, is that this avoids the two "side lobe" responses characteristic of a set with a fairly wide i.f. bandwidth and narrow discriminator. These side lobes occur at the ends of the linear part of the discriminator response and give rise to three tuning points instead of the usual one, though the two outside ones are weaker, and distorted.

By using a discriminator bandwidth that is wide compared to the i.f. bandwidth these side lobes fall well outside the i.f. pass band and are eliminated. Here it is not possible to tune to a side lobe, which has been known, giving rise to complaints of poor a.m. rejection!

Higher St. Budeaux, Devon. A. M. PEVERETT.

Discrimination at H.F.

IT is often suggested that our wives do not like "high-fidelity" because they are more sensitive than we are to the distortion in the treble made more liable by the wider frequency range. But, if this is the case, why is it that, at least in my experience, they never correctly tune in a radio receiver but always leave it sounding more or less "screechy"?

Edgware, Middx. D. J. KIDD.

"Do It Yourself" Interference

MAY I encroach upon your valuable space to answer Mr. Peter Stark Lansley's criticisms of my "Do it Yourself" Interference letter in your issue of December, 1957?

The last thing I want is to damp youth's enthusiasm for scientific knowledge, in fact I have given considerable help to many youngsters with their radio problems.

No, Peter Lansley, my guns were aimed at the designer of the set, not at the user. It would have been quite easy for him to have added an untuned buffer r.f. stage to the regenerative detector and this would have reduced to a negligible risk the possibility of radiating a signal capable of causing heterodyne interference with broadcast reception in the neighbourhood.

I, too, have made my regenerative one-valver although, I admit, this was in pre-broadcasting days. Even in the early nineteen-thirties, to which you refer, there were nothing like so many listeners as today so the chances of causing interference with an oscillating detector were correspondingly less.

I wonder what the Radio Department of the Post Office thinks of this set?

Godalming, Surrey. DOUGLAS WALTERS.

Unidentified TV Station

DURING the afternoons there is a strong TV signal on 55 Mc/s. The frame sync pulses are based on 60 c/s and there appears to be a central colour sub-carrier. Can anyone identify this transmission please?

Stornoway, Isle of Lewis. W. E. GARDNER. (GM3FYR).

PHYSICAL SOCIETY EXHIBITION

THE 42nd exhibition of scientific instruments and apparatus, organized by the Physical Society, will be held at the Royal Horticultural Society's Halls, Westminster, London, S.W.1, from March 24th to 27th. As in the past, the emphasis is on new developments in instruments and research techniques, and space is therefore restricted as far as standard instruments and equipment are concerned.

In all, some 130 manufacturers, research establishments and publishers will be participating, and we give below a selection of the firms in the radio and electronics field.

Admission to the show is by ticket available free from exhibitors or from the Physical Society, 1 Lowther Gardens, London, S.W.7. The exhibition opens on the 24th at 10.30, but admission is restricted to Society members and the Press until 2.0. It opens on other days at 10.0. The closing times on the four successive days are 7.0, 9.0, 7.0 and 4.30.

The Handbook published in connection with the exhibition, which forms a valuable book of reference to scientific instruments and apparatus, is obtainable from the Society, price 6s (postage 1s 8d).

Airmec
Associated Automation
Avo
B.T.H.
Baird & Tatlock
Baldwin Instrument Co.
British Physical Labs.
Burndept
Cambridge Instrument Co.
Cawkell, A. E.
Cinema-Television
Cossor Instruments
Dawe Instruments
Dobbie McInnes
Doran Instrument Co.
Dynatron Radio
Edwards High Vacuum
Ekco Electronics
Electronic Instruments
Electronic Tubes
Elliott Brothers
E.M.I. Electronics
English Electric Valve Co.
Ericsson Telephones
Evans Electroselenium
Ferranti
Fleming Radio
Fortiphone
Furzehill Laboratories
G.E.C.
Hatfield Instruments
Hilger & Watts
Isotope Developments
Johnson, Matthey
Kelvin & Hughes
Labgear
Lintronic
Megatron
Mervyn Instruments
Metropolitan-Vickers
Morgan Crucible Co.
Muirhead
Mullard
Murex
Nagard
Nash & Thompson
Panax Equipment
Philips Electrical
Planer, G. V.
Plessey
Pye, W. G.
Salford Electrical Instruments
Sanders, W. H.
Servomex Controls
Siemens Edison Swan
Solartron
Solus-Schall
Southern Instruments
Texas Instruments
Thompson, J. Langham
Tinsley, H.
Twentieth Century Electronics
Ultrasonoscope Co.
Venner
Wayne Kerr Laboratories

Measuring TV Aerial Performance

2.—Type of Test Equipment Required

By *F. R. W. STRAFFORD**, M.I.E.E.

IN the previous article the selection of a suitable testing site was considered. It was deduced that, to cater for frequencies down to 40 Mc/s, the radiating and test aerials should be not less than 25 feet high and spaced at least 300 feet apart. These distances could be reduced, *pro rata*, if higher frequencies were at the limit of the range. It was also deduced that the standing-wave ratio, due to reflections at the test point, should not exceed 1.02 if directivity patterns involving maximum-to-minimum ratios of 30 dB were involved.

Having settled these factors the choice of the radiating and detecting apparatus can be considered.

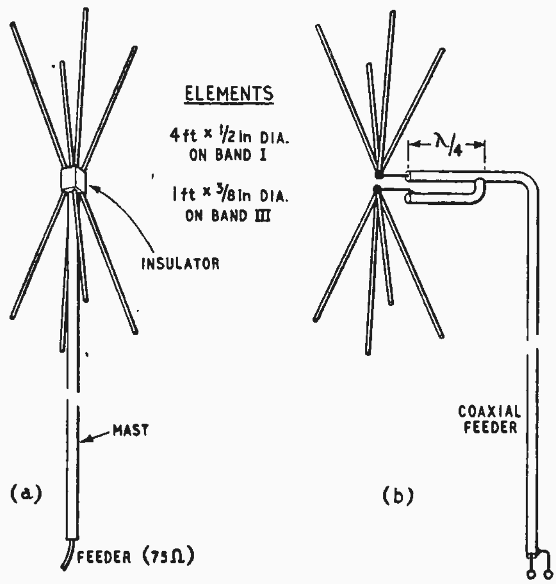


Fig. 5. A suitable wideband test aerial is shown at (a) and with balun at (b).

If the radiating aerial is a half-wave dipole the field intensity at the test point is given by the expression:—

$$\mathrm{E} = \frac{90\sqrt{(\mathrm{P})}\, h^2}{\lambda d^2} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where E is the field strength, in volts per metre.

P is the radiated power, in watts.

h is the height of the radiating and test aerial, in metres.

d is the separation of the aerials, in metres.

λ is the wavelength, in metres.

The e.m.f. appearing across the load resistance of a correctly terminated dipole, that is, fed through a 75-ohm feeder of negligible attenuation terminated with a 75-ohm resistor, is given by:—

$$e = \frac{\mathrm{E}\lambda}{2\pi} \text{(volts)} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

Substituting in equation (4)

$$e = \frac{14.3\sqrt{(\mathrm{P})}\, h^2}{d^2} \text{ (volts)} \quad \ldots \quad \ldots \quad (6)$$

The approximate e.m.f. developed across the receiving dipole feeder termination at the test point can now be calculated in terms of the oscillator power fed to the radiator. It would be convenient to use a standard signal generator for this purpose and such instruments normally supply an open-circuit e.m.f. of 0.1 volt from an internal source impedance (resistive) of 75 ohms. Hence, the power available for radiation from a half-wave dipole with a radiation resistance of 75 ohms will be given by $\mathrm{P} = 0.05^2/75 = 33.3 \times 10^{-6}$ watts. Putting $d = 91.44$ metres (300 feet), and $h = 7.62$ metres (25 feet), in equation (6), the voltage, e, appearing across the receiving dipole termination is given by:—

$$e = \frac{14.3\sqrt{(33.3 \times 10^{-6})} \times 7.62^2 \times 10^6}{91.44^2}\ \mu\mathrm{V} \quad (7)$$

$$= \frac{14.3 \times 5.75 \times 10^{-3} \times 58 \times 10^6}{8370}$$

$= 570\mu$V (slide rule)

The loss in the 300 feet of feeder to the test aerial must be taken into account. If the conventional semi air-spaced feeder similar to that used in fringe TV receiver installations is employed this will introduce approximately 10 dB loss at the high end of Band III. This, with the additional 2 dB loss in the radiator feeder will reduce e to about 140 μV.

Remembering that, in directivity measurements, a maximum front-to-back ratio of 30 dB is to be catered for, a value of less than 5 μV must be detected. The receiving detector would have to possess an extremely low noise factor to permit such a small voltage to be distinguished from the noise. Fortunately, there are a few signal generators which provide an open-circuit output of 0.5 volt which will increase e by a factor of 5 thereby increasing the lowest value to about 23 μV, which is a usable level if a detector with a low noise factor is used.

In any event, a signal generator supplying 0.5 volt will be a certain requirement for impedance measurements to be discussed in the third and final part of the article.

A signal generator is to be preferred over a simple oscillator because it incorporates a calibrated attenuator which can be used to compare the aerials under test. The stability of amplitude and frequency is very good, accurate frequency increments can be made, and the internal modulation can be switched in for identification purposes.

The radiating dipole must possess a wide bandwidth, that is, wider than the bandwidth of the aerial

* Consulting radio and electronic engineer.

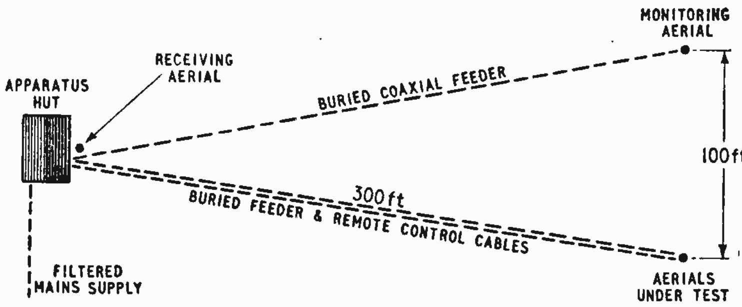


Fig. 6. Layout of testing site.

to be tested. If this requirement is omitted the variation, with frequency, of the gain and directivity will be greater than the true value.

Fig. 5(a) is a skeleton bi-conical half-wave dipole which, if dimensioned as shown, will cover the whole of Band I or III with less than 0.5 dB loss at the edges of the band. It can be used vertically or horizontally according to the desired polarization. This dipole is connected to the output of the signal generator through a low-loss feeder (75 ohms) and erected at a height of 25 feet close to the apparatus hut shown in the site layout, Fig. 6. A balun is provided (Fig. 5(b)) to prevent radiation from the feeder.

The aerial to be tested must be compared with a standard and it has become customary, everywhere, to use a half-wave dipole for this purpose. It should be as near to ideal as possible so that the wideband balanced aerial of Fig. 5 should be used. This, and the aerial to be tested, are in turn mounted on the short rotatable mast mounted on the gimbal mast shown in Fig. 7. This design, using a suitable amount of counterweight, can be erected rapidly by one person and greatly facilitates the work. The rotator should preferably be an electric motor working through a reduction gear-train and designed to be remotely controlled from the apparatus hut because the presence of personnel below the mast is to be avoided, as variations can be introduced thereby. Some excellent rotators, designed for television aerials, are available in the U.S.A., and there does not appear to be any serious import restrictions in obtaining one or two for experimental purposes. These rotators are designed for remote table-top control and the little control panel is usually calibrated in degrees as well as compass bearings. Rotation is restricted to one revolution (360 degrees) so there is no danger of wrapping the feeder round the mast. Overshoot is eliminated by automatic braking and the amount of gear reduction is such that strong winds do not move the aerial from its set position. The r.f. feed from the aerial, and the supply cables to the rotator, are routed underground to the apparatus hut (Fig. 6).

The r.f. feed is connected to a sensitive tuned detector which may range from a well shielded modified television receiver, with a display meter connected in series with the vision diode detector, to an elaborate field-strength receiver costing several hundred pounds. The important requirements are low noise factor, excellent shielding, good gain stability and freedom from frequency drift, if of the superhet type. An important point to remember is that the apparatus is used only as a detector so that the absolute gain is not required to be known, all the measurements being based on comparison with the standard aerial.

If the arrangements so far described are carried out, measurements can proceed along the following lines:— The output of the signal generator is set to about 30 dB below maximum at the desired frequency. The standard dipole is erected and the gain of the detector adjusted so that a convenient reference is established on the display meter. The standard aerial is then replaced by the aerial to be tested and the attenuator on the signal generator is readjusted to restore the reference reading on the display meter. The ratio of the attenuator readings is the gain or loss of the aerial under test compared with the standard. To obtain the directional response the measurements are repeated at 5-degree intervals on the rotator

Unfortunately serious errors may creep in if the foregoing procedure is adopted. An interval of at least an hour occurs between the first and last measurement during which time the detector gain and the output from the signal generator may have drifted, or some fault develop in the aerial under test. For this reason it is strongly recommended that a monitoring aerial be used. This can be identical with the standard dipole and should be erected at a height of about 25 feet and placed about 100 feet to the side of the test point as shown in Fig. 6. In these circumstances it will have a negligible effect upon the measurements. During the course of measurement the receiving detector may be switched over to the monitor and any amplitude drift restored by means of the detector gain control. In this way all uncertainties are removed and the overall accuracy is determined solely by the accuracy of the signal generator attenuator. There is no reason why the output of the signal generator should not be set permanently to maximum and a well-screened, accurate, attenuator with an input and output resistance of 75 ohms, connected in front of the detector. The procedure is the same but there is a distinct advantage in that the aerial under test is more likely to be correctly terminated than if coupled to the first tuned circuit of the detector by

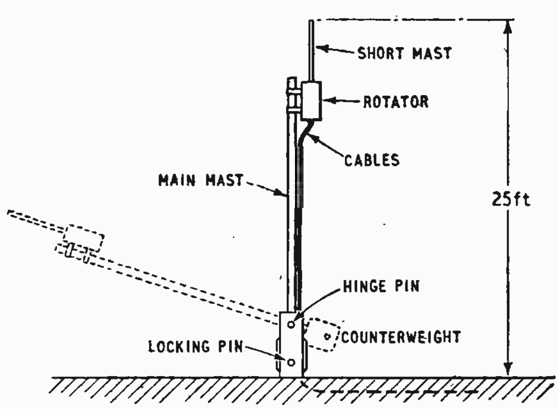


Fig. 7. Rotatable mounting for the test aerial.

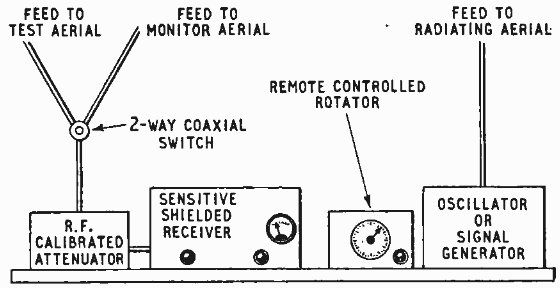


Fig. 8. Layout of the test apparatus.

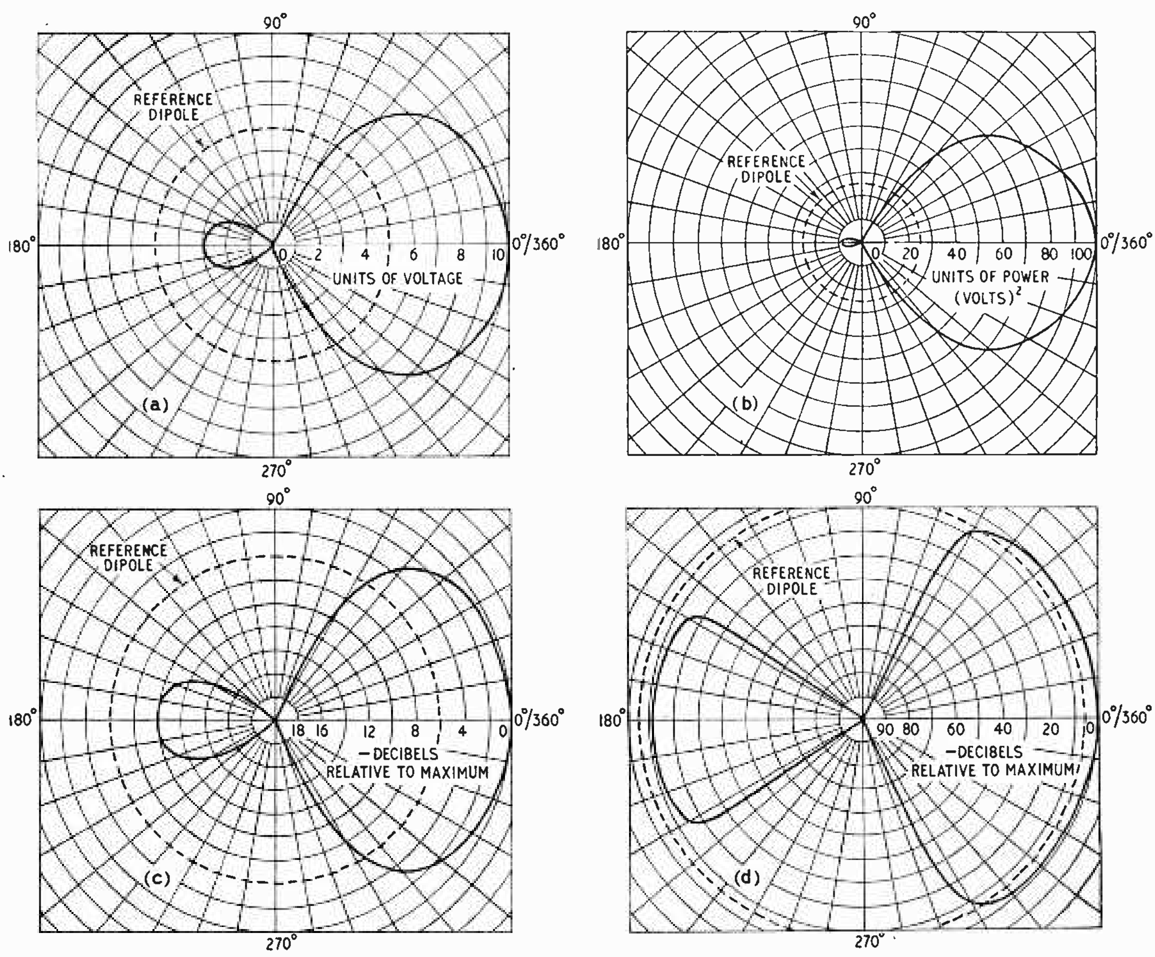
the usual coil coupling or tapping method, which generally causes the input impedance to vary quite a lot with frequency, and to be reactive most of the time! If pre-detection attenuation is not used it is desirable to terminate the test aerial feeder with a 75-ohm resistor and pad this off from the detector input through several hundred ohms, thereby reducing the effective sensitivity of the detector.

Fig. 8 is a layout of the apparatus which includes the preferred pre-detection attenuation and a coaxial switch for switching to either the monitor or test aerial. A check should be made on the possibility of direct pick-up between the detector and the signal generator by the simple process of disconnecting all aerials and terminating the far ends of the feeders with 75-ohm resistors. With maximum output from the signal generator and maximum detector gain the residual pick up should be at least 20 dB below the normal display reference level.

Before serious work is attempted some trial measurements should be taken using a quarter-wave spaced dipole and reflector adjusted for maximum gain. The improvement over the standard dipole should lie between 3 and 4 dB. If the reflector is made into a director, by shortening it and reducing the spacing to one-tenth wavelength, the gain should lie between 4 and 5 dB. Values outside these limits should be treated with great suspicion and the cause traced by step-by-step analyses.

Expressing and Plotting the Results.—*Gain.*—The gain of the test aerial relative to the standard dipole is the maximum gain measured on the axis of the major lobe of the directional response curve. It is customary to express this in dB. Since the feeder termination is resistive either voltage or power ratios expressed in dB give the same answer because

Fig. 9. Different presentations of a polar diagram; in terms of (a) voltage, (b) power, (c) 20 dB attenuation at chart centre and (d) 100 dB attenuation at centre.



10log P_1/P_2 = 20log E_1/E_2 since P is proportional to E^2. It is usual to measure the gain at the vision carrier frequency but it is desirable also to give the figure for the sound carrier frequency if the aerial is likely to be fairly selective, e.g., a Yagi with several elements. In the case of aerials designed to cover more than one adjacent channel a gain-frequency curve should be taken over the range claimed.

There have been suggestions that results have been made misleading by measuring the gain against a standard half-wave dipole and adding 2.2 dB as if the aerial had been compared against an isotropic radiator. But the latter is a hypothetical radiator, convenient in mathematical analysis, but which could not be constructed in practice. Mathematically it is defined as an aerial capable of receiving equally well in *all* vertical and horizontal directions. Such an aerial does not exist. Adding 2.2 dB however, to an aerial with a gain of, say, 4 dB relative to a half-wave dipole certainly glamorizes the result—*caveat emptor*!

Azimuthal Directional Response.—It is usual to plot this in 5-degree intervals in polar co-ordinates, (Figs. 9(a)-(d)), but one must beware of the choice of the amplitude scale. The directional response of a typical H aerial (Fig. 9(a)), is plotted in terms of voltage. The same characteristics plotted in terms of power (voltage squared) look a lot better, (Fig. 9(b)). Plotted in dB, where the centre of the chart is made to coincide with 20 dB, it does not look so good (Fig. 9(c)). When the centre of the chart is 100 dB the properties look even worse (Fig. 9(d)). Directional response characteristics cannot, therefore, be compared merely by casual inspection of the polar diagrams *unless the amplitude scale and notation are standardized* The writer suggests that the response is plotted in dB, and that the centre of the co-ordinate system be 40 dB, since the maximum front-to-back ratio rarely exceeds this value. A great deal of unintentional misrepresentation could be avoided by adopting such, or similar, standards. The directional response should be plotted in heavy lines and that of the standard reference dipole in dotted lines superimposed.

Vertical Directional Response.—It is almost an impossibility to measure this down to Band-I frequencies as it would be necessary to place the aerial under test, at various points, on a huge, insulated, semicircular platform or gantry raised above ground on a radius of 300 feet! An approximate measurement may be made by placing the radiator and test aerial in the horizontal plane (in the case of an aerial designed for vertical polarization), and vice versa for a horizontally polarized aerial. Measurements are then made by the procedure outlined and the results may be regarded as a fair, but doubtful, approximation to the real thing.

Furthermore, it could be argued that the aerial so measured is rarely installed in the manner recommended for the tests; it will, in practice, be erected on a mast, chimney, wall, or in the loft, or even in the viewing room. This being so, why bother to make any measurements, or, at least why not introduce more practical conditions! The answer is simple. Statistically, if a few thousand aerials type A and B, in which type A is the better under the tests outlined, are placed in a variety of sites under normal housing conditions, *on average* type A will give the best picture-to-noise performance. Occasionally the inferior aerial will be the better due to adventitious circumstances. In any event, how else is the performance to be measured?

The general problem of measurement, as discussed in this article, is not confined to television aerials and can be extended to aerials for telecommunications, beacons, radar etc., where the user has the advantage of being able to select a suitably isolated site. In these circumstances the value of aerial comparisons based on the foregoing principles and procedure cannot be doubted.

(To be concluded)

CLUB NEWS

Birmingham.—Modern trends in oscilloscope design will be covered by G. J. Williams (Solartron) when addressing members of the Slade Radio Society on March 14th. Two B.T.H. films will be shown on March 28th. Meetings are held at 7.45 at the Church House, High Street, Erdington. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Birmingham.—Two-metre mobile operation will be discussed by T. Tallboys (G2ATK) at the Midland Amateur Radio Society meeting on March 18th at 7.30 at the Midland Institute, Paradise Street. Sec.: C. J. Haycock (G3JDJ), 360, Portland Road, Birmingham, 17.

Bradford.—D. G. Enoch (G3KLZ) will speak on amateur television at the Bradford Amateur Radio Society meeting on March 4th at 7.30 at Cambridge House, 66, Little Horton Lane. Sec.: D. M. Pratt (G3KEP), 27, Woodlands Grove, Cottingley, Bingley.

Bury.—At the meeting of the Bury Radio Society on March 11th G. Openshaw (G2BTO) will speak on preventing TVI (television interference). The meeting will be at 8.0 at the George Hotel, Kay Gardens. Sec.: L. Robinson, 56, Avondale Avenue, Bury.

Leeds.—The first Northern Mobile Rally is being organized for Sunday, April 13th, by the Spen Valley Amateur Radio Society in co-operation with societies in Leeds and Bradford. Central stations radiating on 80 and 2 metres will be sited in the grounds of Harewood House. Further information from N. Pride, 100, Raikes Lane, Birstall, near Leeds.

Reading.—Lt.-Col. Bower will speak on his experiences as a transmitter in the Far East to members of the Reading Amateur Radio Club on March 29th at 7.30 at the Broad Street Headquarters. Sec.: A. B. Hutchence (G3IKA), 12, Chiltern Bank, Peppard, Oxon.

Sidcup.—The March meeting of the Cray Valley Radio Club will be the A.G.M. Meetings are held on the fourth Tuesday of each month at 8.0 at the Station Hotel, Sidcup. Sec.: S. W Coursey (G3JJC), 49, Dulverton Road, London, S.E.9.

Wanstead.—The Wanstead and Woodford Radio Society has been reorganized, and is now known as the Wanstead, Woodford & District Radio Club. The H.Q. is still at Wanstead House, The Green, London, E.11, where members have use of a self-contained building in the grounds. M. M. D'Arcy (G3AGL) continues as chairman with Ken Smith (G3JIX) as secretary. A series of lectures on morse and radio theory are arranged for Wednesday evenings at 7.30, and general meetings are held each Friday at 8.0.

Wellingborough.—Mullard's film lecture on the history and development of the cathode-ray tube will be given at the meeting of the Wellingborough & District Radio and Television Society on March 13th. The meeting will be held at 7.30 at the Wellingborough Technical College. Sec.: P. E. B. Butler, 84, Wellingborough Road, Rushden.

Scatter Propagation

DIGEST OF PAPERS SUBMITTED TO THE I.E.E. SYMPOSIUM

A SYMPOSIUM on long-distance propagation on frequencies above 30Mc/s was held at the Institution of Electrical Engineers on 28th January, at which the forenoon session was devoted to the subject of forward scatter propagation *via* the ionosphere, and the afternoon and evening sessions to that of propagation to distances beyond the horizon *via* the troposphere. There were eleven papers on the first subject and twelve on the second and a considerable portion of each session was devoted to animated discussion on the contents of the papers. From this mass of detailed material we can only bring out some points of general interest, as they appeared to us.

Ionospheric Forward Scatter Propagation.—The focus of attention was mainly on results obtained over the ionospheric forward scatter circuit between Gibraltar and places in the U.K., at distances of approximately 1,100-1,300 miles (1,760-2,080 kilometres) on frequencies of 37, 48 and 70Mc/s. The scattering appears to take place at a height of 80-90 kilometres, this being assumed to be in the ionized region at the bottom of the E layer, it being necessary to employ directive aerials to "illuminate" a scattering area at this height, which is mutually "visible" to the transmitting and receiving aerials. For the longer distances some allowance must be made for a small amount of "bending" in the troposphere. The strongest signals appear to occur in the frequency range 30-50Mc/s, and their structure indicates that they are composed of a low-level fluctuating background on which are imposed high-level bursts. The low-level component has been ascribed to scatter from "turbulences" in the ionization, but there seems to be considerable uncertainty as to whether this is, in fact, the cause. The high-level bursts are of fairly certain origin, and interesting evidence of a diurnal movement across the great circle path in the direction from which they come was given as proof that they are due to meteoric activity. As a result of variations in the incidence of their sources the scatter signals have a pronounced diurnal variation, with a maximum at 0400-1200g.m.t. and a minimum around 1800g.m.t., the latter corresponding to a minimum of meteors. They also have a seasonal variation such as to produce maxima in July and December and minima in March and October. However, a scatter circuit does not require frequency changes and is not interrupted by ionospheric disturbances.

Due to the generally low level of the scatter signal and the necessity for the use of high-gain receiving aerials, the system is particularly susceptible to the effects of interference, and a truly formidable list of interference sources which were observed within the useful frequency range was given. As if this were not bad enough, there is also, under high sunspot activity conditions, the problem of self-interference, for back radiation from the transmitter can be scattered at the ground and then propagated in a forward direction *via* the F_2 layer so as to cause interference at the receiver. There is also interference from round-the-world echoes. Again, particularly when sporadic E is present, the scatter signals can be propagated in an unwanted manner so as to interfere with other services.

In fact it appeared evident from some of the papers, and more particularly from the discussion, that many people are of opinion that ionospheric scatter systems are severely limited in scope, and have few useful applications in the field of civil communications, though their military applications may be advantageous. Nevertheless in the intensive study which has been given to the subject much useful knowledge about the ionosphere and about the appropriate "hardware" has been gained. It is only fair to add that, despite the difficulties, the U.S. authorities are using several such links upon an operational basis.

Tropospheric Scatter.—The 12 papers devoted to measurements and predictions of field strength of signals propagated beyond the radio horizon covered wavelengths of from 10 metres down to 3·2 cm; 30Mc/s to 9,600Mc/s. The lower frequencies are, however, more suitable for ionospheric scatter propagation, but it must not be thought that under no conditions will the lower frequencies be propagated in the troposphere. As far back as the late 1920s and early 1930s Guglielmo Marconi carried out some interesting investigations on beyond-the-horizon transmission on 30Mc/s achieving ranges of 170 miles with the radio horizon at about 20 miles. Later experiments on 600Mc/s, then regarded as in the microwave region, demonstrated that even with the crude (by modern standards) apparatus then available, reception up to nine times the optical range for the siting of the aerials was achieved. In retrospect these tests were most significant, but at that period the pressing considerations of world-wide coverage took charge and further activities were directed along the more profitable channels of short waves.

Amateur workers continued to explore the 60-Mc/s frequencies, however, and a suitable tribute was paid in the discussion to their contributions in the 1930s to accumulated knowledge on v.h.f. propagation *via* the troposphere.

From the nature of the papers submitted to the symposium it is very apparent that over the past five to six years a vast amount of scientific data has been compiled on radio-wave propagation in the troposphere beyond the radio horizon. It is now generally accepted that reasonably reliable communication is practicable at distances between 100 and some 500 to 600 miles, utilizing tropospheric scatter technique and that the most suitable radio frequencies are those above about 300Mc/s. Lower frequencies are propagated in this medium and under certain con-

(*Continued on page* 125)

ditions television frequencies of 40Mc/s upward, and v.h.f. broadcasting frequencies of 85 to 95Mc/s, can be received at surprisingly long ranges as shown by measurements contained in one of the papers.

It is also known now that, unlike the ionosphere scatter systems, the troposphere scatter transmissions can support a wide bandwidth making multi-channel communication systems and long-distance television transmission possible. From the interference by Continental stations that U.K. viewers have experienced during the past year or so, and by the interference to v.h.f./f.m. broadcast that is caused by Continental stations and experienced mainly on the Channel coast, there is no doubt that tropospheric scatter propagation is definitely operative on 85 to 95Mc/s. In this connection one of the papers was devoted to the results of a series of tests conducted by the B.B.C. in 1946-1947 over distances ranging from 135 miles to 600 miles and on frequencies from 41 to 68Mc/s, 88 to 95Mc/s, 180 to 200Mc/s and 470 to 585Mc/s over land and over sea. The main purpose of the investigation was to compile data that would assist in the planning of common-frequency working of TV and v.h.f./f.m. stations in the United Kingdom. Later these results were handed over to the C.C.I.R. as a contribution to the tropospherical data being compiled for international use.

Apart from the microwave investigations, for which paraboloid-type aerials were customarily used, aerial systems for the lower frequencies were generally Yagis stacked vertically or arranged as side-by-side systems or a combination of both were often used. From 200Mc/s up, these were often backed by a reflecting screen in place of element-type reflector rods. These systems sufficed, without unduly high transmitter radiated powers, to enable investigations to be conducted up to 400 or 500 miles.

The nature of the received signal has led to the conclusions that the so-called scatter form of propagation is more often than not a combination of reflection and scatter, the reflection components often predominating and giving rise to unusually strong signals beyond the radio horizon. There is a sharp fall in field strength as a rule just beyond the horizon threshold and this may amount to 50dB below the free-space field for the equivalent distance. There are diurnal and seasonal fluctuations in field strength which vary considerably with the working frequency and signals are generally stronger at night than during daylight by a matter of about 8dB, while the variation over the 24 hours can amount to about 13dB. Signal strength is generally lower in winter than in summer. These figures apply to the 3,000-Mc/s region and are slightly smaller for lower frequencies and larger for higher frequencies; they can be taken as fair averages. As 3,000Mc/s and higher signals are enhanced by fog and deteriorate in rain, while over the whole range aircraft echoes are very significant.

These are general observations, but signals are subject to considerable variation in strength, as the resulting signal beyond the horizon usually consists of an incoherent signal, due to reflections from irregularities in the refractive index of the troposphere, or atmospheric turbulence, or other effects and a coherent signal arising from some kind of elevated reflecting layer in the troposphere. This can be either a sharp discontinuity in the refractive index or in the temperature or humidity gradient. Reflecting layers can also be formed by other atmospheric conditions. When it amounts to an inversion, temperature or humidity, strong and sustained reflections occur giving rise to abnormally strong signals in the trans-horizon region. The height in the troposphere of these reflecting layers can be anything up to the limit, which is variously assumed to be about 6 miles above the ground, so that radio reception in aircraft flying at heights up to about 30,000ft is subjected to the variations prevailing in the troposphere. Some investigations have been made and are at present continuing into reception conditions in aircraft flying above the tropopause. This is an arbitrary boundary which can fluctuate between 30,000 and 40,000ft according to prevailing conditions and other factors.

Despite the vast amount of data that has accumulated and the conclusions reached regarding the probable behaviour of radio waves beyond the radio horizon from postulated theories, there is still sharp divergence in opinion as to the primary mechanism of propagation in the troposphere. Some authors of papers were strongly in favour of reflections contributing the major part, others held that scatter in its more limited sense was the dominating factor, but the true explanation is more than likely a contribution of all known mechanisms that project a signal into the trans-horizon region. And several speakers expressed this view in the subsequent discussion.

There is still much to be learnt about this medium of wave propagation; for example, at the highest frequencies explored, *circa* 10,000Mc/s, there appear to be factors which influence propagation and which cannot be satisfactorily explained from available data. But no doubt time will rectify this omission, as it does in most problems of a scientific nature, where, when sufficient evidence is forthcoming, theories can be formulated to account for all the phenomena encountered.

Commercial exploitation of trans-horizon propagation does not seem to have gone very far, which may be due to the incomplete data so far compiled, or to the time it takes to assimilate the data and formulate conclusions that are convincing to the commercial mind as well as to the physicist. It is admitted that at times signal strengths can be very low and, of course, economics enter into the picture, since it is unrealistic to install transmitting and receiving equipment of adequate power and sensitivity to cope with the worst conditions, whereas half the power and sensitivity or less would suffice for most of the working time. Cost of aerials has also to be taken into account, since for all forms of scatter communication relatively high-gain aerials have to be used.

It was mentioned in the discussion that in an overseas chain of microwave radio links in which the transmitting and receiving frequencies were repeated at intervals signals occasionally hopped over the intermediate relays to the next one using the same frequency. The reliability factor was not quite good enough to justify closing down the intermediate relays, but no doubt if equipment more in keeping with the signal strengths in the trans-horizon region had been in use some economy of this kind might have been possible for part of the working time. It would seem, therefore, that, for the present at least, line-of-sight, or just-over-the-horizon, spacing of relay links is likely to remain the basic policy for long-distance microwave links.

Magnetism in Materials

(Continued from p. 74 of previous issue)

3. Commercial Magnetic Materials and Domain Theory

By D. H. MARTIN, Ph.D.

DURING the last 60 years the systematic search for new and better alloys for application in electrical and communications engineering has produced a remarkable range of materials whose technologically important properties—permeabilities, coercivities, etc.—are extremely sensitive to minute quantities of impurities and residual stresses and to variations in heat, mechanical and magnetic treatments. The domain theory which I have outlined in the foregoing pages sets out to relate these properties to the basic *structure-insensitive* constants of the materials, that is to the spontaneous magnetization I_s, the anisotropy constants K, and the magnetostriction constants λ. These are hardly affected by impurities and strains. In doing so it has clarified a bewildering collection of empirical data and, in recent years, has served as a valuable guide in the development of special materials, as I plan to illustrate by reference to some commercially important materials.

The usefulness of a magnetic material is determined largely by the shape and size of its *hysteresis loop* though its mechanical and electrical properties and its cost will often have to be considered. When a sample is subjected to an alternating field the induced magnetization varies cyclically as illustrated by the family of hysteresis loops in Fig. 14, each loop being appropriate to a particular peak field. The hysteresis properties of a material are often adequately described by quoting values for its coercivity, its initial and maximum permeabilities, its saturation induction and its hysteresis loss. These may be defined with the aid of Fig. 14. The magnetic induction B induced in a specimen by a field H is equal to $(H+4\pi I)$ (in the e.m.u. system of units) where I is the intensity of magnetization of the specimen. B is more directly measurable than I and is therefore more commonly quoted than I itself. The hysteresis loops in Fig. 14 are B versus H loops. In large fields, I, and therefore (B-H), reach constant values (when all the domains are aligned with the field) and this value of (B-H) is the *saturation induction* B_s. The coercive force is that field required to reduce the induction to zero, and for the loop in which saturation is attained the coercive force is known as the *coercivity*, H_c, of the material. The "normal magnetization curve" is the dotted line in Fig. 14, that is the line joining the tips of successive loops. The *permeability*, μ, is the ratio of B to H for a point on the magnetization curve, and clearly depends on the field, generally as shown in Fig. 15. The *initial permeability* μ_0 is that in very low fields and μ_m is the *maximum permeability*. I have already described how hysteresis arises from irreversible domain wall motion, and with this there is associated a generation of heat. It can be shown that the hysteresis heat per cycle W_H is directly proportional to the area enclosed by the hysteresis loop. That this is an important specification for a material to be used in a power transformer core is brought home by the estimate of Yensen in 1936 that about 0.4% of all the electrical power then used in the United States was dissipated as heat in transformer cores. Hysteresis loss is also important in communications equipment, not only as a measure of lost power but because hysteresis causes harmonic distortion.

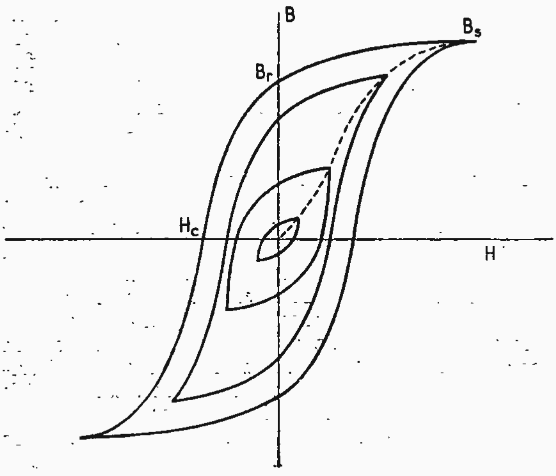


Fig. 14. Family of hysteresis loops. The dotted line is the normal magnetization curve.

The electrical resistivity ρ of a material is normally an important specification. This is because of the undesirable effects of *eddy currents* which are induced in core materials, by ordinary electromagnetic induction, when their intensity of magnetization is changing with time. They are greater the higher the frequency of alternation of H. Eddy currents dissipate heat by joule heating and thus cause power loss. In high-frequency applications they also limit the penetration of the magnetic field into a core material and therefore cause an apparent decrease of μ with frequency. Eddy currents are smaller the larger the resistivity of a material, and, for high-frequency applications a large ρ is therefore desirable. In order to reduce the eddy-current effect, transformer and inductor cores and the magnetic parts of motors and generators are normally laminated, that is made up of thin sheets which are electrically insulated from each other. Power transformer laminations are usually 0.014 in thick, and for high-frequency applications cores are made of strip, sometimes as thin as 0.002 in, or of powdered alloys.

The coercivities of commercially important materials fall within the range from 0.004 oersted up to more than 4,000 oersteds, that is over six orders of magnitude. Maximum and initial permeabilities vary over almost as wide a range from about 1.0 up to $\mu_m \approx 1{,}000{,}000$ and $\mu_0 \approx 100{,}000$. Materials may be generally classified as magnetically *soft* or *hard*. Soft materials are those having H_c less than an oersted or so, and high permeabilities, and are mainly used in transformers, inductors, motors and generators; in fact in all devices requiring large, and sometimes rapid, changes in induction upon the application, removal, or reversal of small applied fields. Hard materials are those with H_c greater

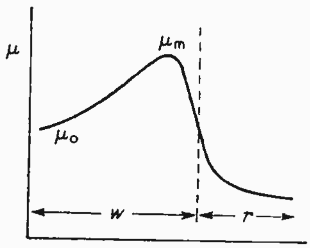


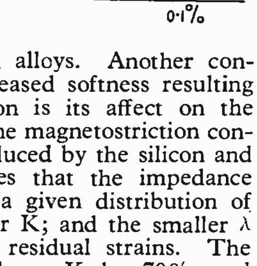
Fig. 15. Variation of permeability μ with field H. The drop in permeability occurs when wall motion, ω, gives way to rotation, r.

than about 50 oersteds and are used to construct the permanent magnets required for loudspeakers, microphones, microwave generators and numerous other devices. With the application of magnetic materials in recent years as computer storage and register elements there has been developed a third class of materials, those with rectangular hysteresis loops. In the following pages I shall discuss some of the important materials belonging to each of these three groups.

Magnetically Soft Materials.—Iron is the most readily available magnetic element and almost all of the commercially important materials contain a large proportion of it. For reasons which will be given later it is seldom used magnetically in an unalloyed form except in large electromagnetic machinery. During the last 60 years, however, extensive magnetic studies have been made of pure iron and they illustrate remarkably the importance of purity and freedom from mechanical strain in achieving magnetic softness. Improvements in the techniques of purification since 1900 have led, for example, to an increase of more than a thousandfold in the maximum permeability of laboratory specimens. High purity commercial iron has μ_m in the range 5-10,000 and H_c about 1.0 oersted. Laboratory specimens, purified by a series of annealing treatments in vacuum and in hydrogen at temperatures up to 1,400°C, followed by slow cooling at less than 5°C per minute to avoid residual mechanical stresses, have μ_m as high as 350,000 and H_c about 0.01 oersteds. I have described earlier how the domain theories explain the extreme sensitivity of permeability and coercivity to minute quantities of impurities and stresses. Imperfections of these kinds impede the movement of domain walls. The impurities which are in practice most troublesome are carbon, oxygen, nitrogen and sulphur. These have low solubility limits in iron; that is to say, when present in quantities greater than 0.007%, 0.01%, 0.001% and 0.02% respectively, the impurity atoms no longer fit into the iron crystal lattice but form precipitated islands or "inclusions" of various chemical compounds; for example carbon may appear as a precipitate of cementite (Fe_3C). These inclusions are thought to be most effective in impeding wall movement when a given amount of impurity is distributed through the material in the form of inclusions having diameters about equal to the width of a domain wall, in iron about 10^{-5} cm. Even when present in amounts less than the solubility limit impurity atoms distort the lattice, setting up stresses which impede wall motion. The effect of carbon and oxygen on the hysteresis loss of pure iron is illustrated in Fig. 16. A serious defect of early magnetive irons was "ageing," the deterioration of the soft properties with time. This is due to a slow precipitation of impurities into inclusions of a more effective size.

For applications involving alternating fields iron alloyed with up to 5% *silicon* is superior to unalloyed iron, and is used in large quantities in power transformers, motors and generators. The added silicon brings about several improvements which lead to a greatly reduced power loss. First, the electrical resistivity increases approximately in proportion to the percentage of silicon, rising from about 14 micro-ohm-cm for unalloyed iron to about 80 micro-ohm-cm for 6% silicon-iron, a sixfold increase. This leads to a considerable reduction in eddy-current losses. Secondly, the addition of silicon to iron increases its permeability and reduces its coercivity, in other words decreases its hysteresis loss. Unlike the impurity elements, silicon forms solid solutions in which the silicon atoms simply replace some of the iron atoms in the crystal lattice without undue distortion. The improved soft properties are due partly to the chemical reactions, between the silicon and the impurities initially present in the iron, which take place during the preparation of the material. These reactions lead to the removal of some of the impurities as slag, and to carbon being precipitated in the form of graphite, rather than cementite or pearlite. In this form it is less harmful, probably due to its coagulation into larger inclusions. Ageing is completely

Fig. 16. Dependence of the hysteresis loss per cycle, W_H, at a peak induction of 10,000 gauss, on the percentage of carbon and oxygen in iron. (Yensen)



absent in good silicon-iron alloys. Another contributory factor to the increased softness resulting from the addition of silicon is its affect on the anisotropy constant K and the magnetostriction constant λ. These are both reduced by the silicon and the domain theory indicates that the impedance offered to wall motion by a given distribution of impurities is less the smaller K; and the smaller λ the less important are the residual strains. The addition of 7% silicon reduces K by 70%, and λ falls to zero, and extremely soft properties are exhibited by alloys containing 6-7% silicon. Two factors severely limit the usefulness of alloys containing more than about 4½% silicon, however. First, the saturation induction B_s is reduced by the addition of silicon, 4% silicon causing a 10%

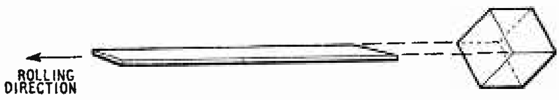


Fig. 17. Orientation of the cubic axes of the crystals in grain-oriented silicon-iron.

decrease in B_s, and for applications where a high induction is the prime requirement (in motors and generators for example) alloys containing 1.5% silicon or less are therefore used. Secondly, alloys containing more than 5% silicon are extremely brittle. For transformers, where a high permeability, rather than a high induction, is required, the silicon content employed is normally about 4%, and typical values for μ_o, μ_m, and H_c are respectively 800, 8,000 and 0.6 oersteds.

The reduced influence of impurities and strains when K and λ are low is demonstrated in a remarkable way by a ternary alloy containing silicon, aluminium and iron. By adjusting the proportion of these materials it is possible to make an alloy for which *both* K and λ are almost zero. This occurs at about 9.6% silicon and 5.4% aluminium; as the silicon and aluminium contents are varied through this critical composition K and λ change sign. This alloy is magnetically very soft with $\mu_o \approx 35{,}000$, μ_m about 120,000, H_c about 0.5 oersted and $B_s \approx 10{,}000$ gauss. The applications of this alloy, which is known as Sendust, are very restricted due to its brittleness. The production of very soft materials by adjusting composition to give near-zero K and λ has great commercial importance, however, as will be illustrated later in the discussions of certain nickel-iron alloys and ferrites.

I return now to the silicon-iron alloys to discuss a comparatively recent development in their preparation which has led to greatly improved magnetic properties. Ordinary "hot-rolled" 4% silicon-iron for power transformer cores is prepared by rolling the hot alloy into sheet, by successive passes and re-heating, followed by an anneal at about 900°C. Laminations are then stamped out of the sheet, which is normally 0.014 in thick, and for the best performance the strains remaining after stamping are relived by a further anneal. The new method of treatment involves rolling the alloy when it is cold, not hot, and this results in the growth, during subsequent annealing treatments, of crystals which have a distinct preferred orientation. The situation is illustrated in Fig. 17. The crystals in the sheet are still irregularly shaped, but their crystal axes, which fix the atomic arrangement within them, are not randomly oriented. Each crystal lies close to the orientation illustrated in the figure, that is with the [100] direction, an "easy" direction in terms of domain theory, parallel to the rolling direction of the sheet. The sheet therefore approximates to a single crystal. Now in an earlier section dealing with domain processes I described how a single crystal may be magnetized to saturation in a very low field provided the field is applied in an "easy" direction, that is a [100] direction in iron. For fields in [110] and [111] directions the induction in a crystal rises rapidly to $B_s/\sqrt{2}$ and $B_s/\sqrt{3}$ respectively, but from there onwards larger fields are required to increase the overall induction, by domain rotation. In a polycrystalline sample in which the crystallites, or "grains," are randomly oriented, wall motion will therefore produce a rapid rise to somewhere between B_s and $B_s/\sqrt{3}$, in fact to $B_s/1.5$ in silicon-iron. In *grain-oriented* materials, however, when the field is applied in the rolling direction, domain wall motion will lead to an induction close to B_s, just as it does in a single crystal magnetized in an easy direction. The great improvement in the induction thus attained at fields greater than about one oersted is illustrated in Fig. 18. (There is also an increase in the permeability at inductions below the "knee" of the magnetization curve, and this is not as readily explained. It is probably due to a preferred domain orientation arising from the difference in dimensions of the sheet in the three [100] type directions.) The permeability perpendicular to the rolling direction is less than that parallel to it, as would be expected since this direction is close to the [110] directions of the crystallites. Unless the field applied to a specimen is everywhere parallel to the rolling direction full advantage cannot be taken of the improved properties. If possible, therefore, strip-wound cores rather than "E" or "I" laminations should be used. Cold-rolled grain-oriented 3% silicon-irons are available under various trade-names, among them Hypersil, Crystalloy and Alphasil, and typical values for μ_o, μ_m, and H_c are 2,000, 30,000 and 0.25 oersteds, when magnetized in the optimum direction; the improvement over non-oriented material is very marked. They are used in high-efficiency power-frequency transformers as well as in audio-frequency power-transformers, chokes, pulse transformers, etc., in which low losses are essential. For these applications cores are normally strip-wound using material selected from a range of thicknesses down to 0.002 in.

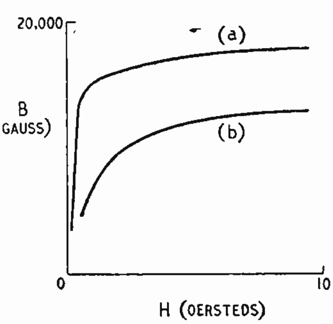


Fig. 18. Magnetization curves for (a) grain-oriented 3% silicon-iron and (b) 4% non-oriented silicon-iron.

Certain alloys of iron with between 40% and 90% nickel have much higher permeabilities, smaller coercivities and hysteresis losses, and larger resistivities than the silicon-irons. For example, typical values for H_c, μ_m and μ_o are 0.3 oersted, 25,000 and 2,500 respectively for 45% nickel-iron ("45-Permalloy") and 0.05 oersted, 100,000 and 8,000 for 78.5% nickel-iron ("78-Permalloy"). Hysteresis losses at a peak induction of 5,000 gauss are of the order ten times lower than for non-oriented silicon-iron. Compared with iron, however, the saturation induction is low; 16,000 gauss for 45% and 10,800 gauss for 78.5% nickel-iron compared with 21,500 gauss for iron. It is partly due to this that they have not replaced silicon-iron in electrical power installations, generators, motors and transformers, which operate at high inductions. Their applications are also restricted by their high cost, which arises from the high nickel content and the refined

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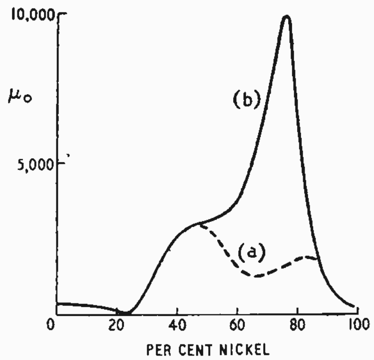


Fig. 19. Variation of initial permeability μ_o with the nickel content of nickel-iron alloys. (a) Slow cooling. (b) Treatment includes rapid cooling from 600°C (from Bozorth).

methods of preparation. They are very widely used, however, in communication engineering where very soft materials are essential. The remarkable properties of these alloys are mainly due to the special considerations, discussed shortly, but high purity and freedom from residual strains are again most important. Because nickel-irons are normally required in smaller quantities than the sheet-steels used in power engineering it is possible to adopt more highly specialized techniques in their preparation. The basic metals are obtained in very pure form and melted together in an induction-furnace in a controlled atmosphere or in vacuum. The cast ingots are then subjected to a series of rolling treatments at different temperatures to produce a sheet of the required thickness, which for high-frequency applications may be as little as 0.001 in. The preparation is completed by annealing, usually in hydrogen at a temperature in excess of 1,000°C. The final anneal normally takes place after the strip had been wound into the desired form of core.

The best properties are found in alloys in two composition ranges, those containing about 50% nickel and those containing about 80% nickel. Figs. 19 and 20 illustrate the variation of initial and maximum permeabilities with composition, and show the optimum ranges at about 50% and 80% nickel. In each figure two curves are plotted recording the effect of different heat treatments. The curves (a) correspond to a treatment in which the final process is cooling slowly from a high temperature down to room temperature, while for curves (b) the final process is a rapid cooling from about 600°C to room temperature. Now Bozorth (1953) has measured K and λ for nickel-iron crystals which have been subjected to similar heat treatments. He found that each of the maxima in the permeability curves of Figs. 19 and 20 occur very close to compositions for which the magnetostriction constant *for the "easy" direction* passes through zero. This is precisely what the domain theory predicts. He also found that the magnitude of the anisotropy constant for rapidly cooled 78.5% nickel-iron is considerably smaller than the magnitude of K at each of the other zero-λ compositions, and this clearly explains why the μ_o and μ_m peaks for this alloy are higher than the other subsidiary peaks. The complicated behaviour of the nickel-iron alloys is thus simply related to their basic constants K and λ. The fact that K and λ depend upon heat-treatment seems to contradict the claim that they are "structure-insensitive" constants. In nickel-irons, however, a rather special process takes place in the range of compositions where K and λ are sensitive to heat treatment. At temperatures above 600°C the iron and nickel atoms are randomly distributed in the crystal lattice. If the temperature is reduced the alloys become "ordered", that is each iron atom tends to become surrounded by the same number of atoms of nickel and of iron as every other iron atom. The values of λ and K, and also of I_s and the Curie temperature, depend to some extent on the degree of order. If an alloy is cooled slowly from above 600°C to room temperature ordering occurs but if the cooling is rapid then the random mixing characteristic of the high temperature is "frozen in", and remains.

Commercial development of nickel-iron alloys has been mainly at the two composition ranges 45-50% and 75-80% nickel, and most commercial alloys contain small quantities of other metals. These are added to increase the resistivity over that of the binary alloys and to reduce the sensitivity of the permeabilities to slight variations in heat treatment (by suppressing the ordering process). In some cases the added metals have even markedly improved the magnetic properties, probably because the anisotropy constant K happens to be smaller at the zero-λ composition when they are present. Typical commercial alloys are the Mumetals, containing 72-76% nickel, 5% copper and 2% chromium; Permalloy C containing about 77.4% nickel, 3.7% molybdenum and 5% copper; and, at the lower nickel content, Radiometal with about 50% nickel and 50% iron and Permalloy B containing 50% nickel and 1% manganese.

The high-nickel alloys are useful especially because of their remarkably high initial permeabilities, up to more than 50,000 (though it is difficult to retain the full permeability when fabricating cores). They are employed in thin strip form, for example, in wide-band low signal transformers, in filters, for loading telephone cables, for magnetic screening and in many other devices of the communications industry. Mention must be made of the alloy known as Supermalloy reported in 1947 by Boothby and Bozorth, which is magnetically softer than any other polycrystalline material. Its composition is 79% nickel, 5% molybdenum, 15% iron and 0.5% manganese and by a series of special rolling and heat treatments a material is produced having μ_o as high as 150,000, μ_m over 1,000,000 and H_c about 0.005 oersted. Its hysteresis loss at a peak induction of 5,000 gauss is only 5 ergs/cm^3 compared with about 500 ergs/cm^3 for silicon-iron and about 50 for ordinary Permalloys and Mumetals.

The low-nickel alloys with 45-50% nickel have

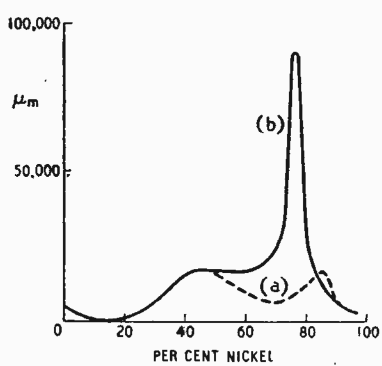


Fig. 20. Variation of maximum permeability μ_m with the nickel content of nickel-iron alloys. (a) Slow cooling. (b) Rapid cooling from 600° C. (from Bozorth).

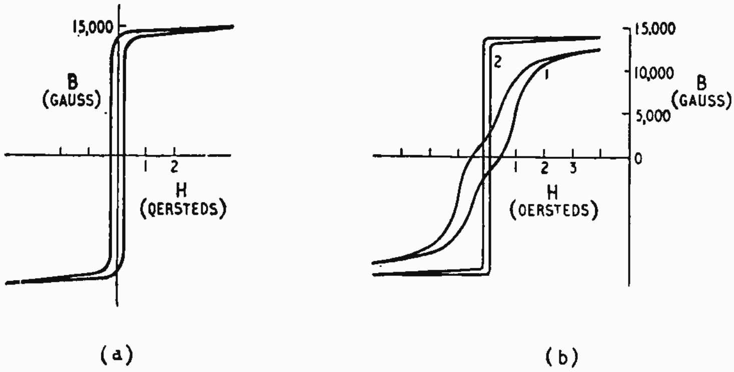


Fig. 21. (a) Hysteresis loop of a grain-oriented 50% nickel-iron alloy. (b) Curves 1 and 2 show respectively the hysteresis loops of 65-Permalloy before and after treatment in a magnetic field (after Bozorth and Dillinger).

smaller initial and maximum permeabilities than the high-nickel group but their saturation inductions are higher (16,000 compared with 6-8,000 gauss) and consequently they have higher permeabilities at high inductions. Their properties are similar to those of the very best quality grain-oriented silicon-iron. They are used for example in small audio-frequency power transformers, and in chokes, relays etc., when a d.c. polarizing current is present, since they have high incremental permeabilities at fields in excess of an oersted or so.

A third group of nickel-iron alloys typified by Rhometal and Permalloy D contain about 36% nickel and find some uses because of their high resistivity (about 90 compared with 45-60 micro-ohm-cm for other nickel-iron alloys and silicon-irons) although they have inferior permeabilities. Eddy current effects are reduced to the extent that their apparent initial permeabilities are almost constant at about 1,000 up to 100 kc/s. when they are in the form of 0.004 in strip, and up to 1 Mc/s. when 0.001 in thick, and they are employed in high-frequency and pulse work.

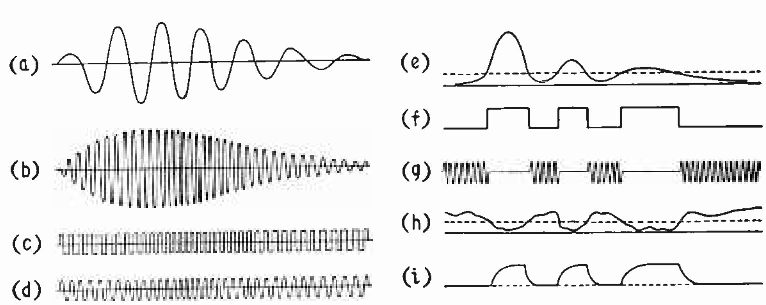
By appropriate cold-rolling and annealing it is possible to produce a preferred grain orientation in nickel-iron alloys containing between 50 and 70% nickel. As in the grain-oriented silicon-irons the permeabilities at high inductions are thus considerably increased, but in the nickel-irons the type of orientation is such that there are easy directions both parallel to *and perpendicular to* the rolling direction. Grain-orientation is used in the commercial 50% nickel-iron known as H.C.R. This material is almost saturated in fields as low as 0.2 oersted as is to be expected from the domain theory of magnetization in an easy direction. Remanence is high for the same reasons and the hysteresis loop is consequently almost rectangular having nearly vertical sides, as illustrated in Fig. 21(a). Another effect likely to have increasing importance as the demand for rectangular-loop materials grows is *domain-orientation.* It is found that some materials, in particular the 50-80% nickel-irons, respond to the application of a small magnetic field as the material cools during the final annealing operation. The effect is to make the hysteresis loop more rectangular, as shown in Fig. 21(b). Only materials having comparatively high Curie temperatures and rather low anisotropy constants exhibit these effects. Under these conditions when the material cools through its Curie temperature and becomes ferromagnetic the applied field saturates the material and, since the temperature is still high enough for the atoms to be comparatively mobile, some sort of strain relief occurs. When the material has reached room temperature and the field has been switched off the specimen contains only domains magnetized almost parallel to or anti-parallel to the original field direction since, with domains in these directions only, the crystals are in their least strained condition; domains magnetized perpendicularly to the preferred directions would introduce magnetostrictive strain. The detailed nature of the strain relief which occurs during magnetic-cooling is not yet fully understood but the uni-axial nature of the resultant material causes the knee of the magnetization curve and the remanent magnetization to be high, as in the case of a single crystal magnetized in an easy direction. Deltamax, Permalloy F and H.C.R. are materials which are *both* grain- and domain-oriented and applications of their rectangular loop properties are mentioned later.

To the long list of commercially available soft magnetic materials there has been added, during recent years, a range of non-metallic materials known as ferrites which have found important applications at radio frequencies, where they compete with powdered iron or nickel-iron as core materials for high Q, loading and filter coils and wide-band high-frequency transformers. The nature of the spontaneous magnetization in the ferrites has been discussed in an earlier section. They are intimate mixtures of iron oxide with oxides of divalent metals such as magnesium, manganese, nickel and cobalt and they have domain structures and behave magnetically like the ferromagnetic metals in most respects. In fact, the magnetism of the ferrites has probably been known for much longer than that of iron metal, because lodestone, the naturally occurring ore which was used for centuries for magnetic compasses, is mostly magnetite, the simplest of the ferrites. The special feature of the ferrites is their high electrical resistivity, and their application, mainly in high-frequency work, is new only because suitable techniques of preparation and fabrication have but recently been developed. The soft ferrites are known commercially in this country as Ferroxcubes and there are two main types, A and B. Ferroxcube A is a manganese-zinc ferrite, that is, an intimate mixture of the oxides of iron, manganese and zinc. It is prepared by carefully mixing the three oxides and grinding them to a fine powder, pressing the mixture in a steel die to the required shape and then firing at between 1,000°C and 1,400°C in a controlled atmosphere. The final product is hard and may be ground to close tolerances. It is not a bonded powder, but is quite homogeneous. During the firing process the oxides inter-diffuse and the crystals of the final product each contain, within a cubic latice of oxygen atoms, atoms of iron, manganese and zinc. Other ferrites are produced in a similar fashion; Ferroxcube B, for example, is a nickel-zinc ferrite. The d.c. resistivities of the ferrites are from 10^8 to 10^{12} times higher than those of metallic iron, and they are therefore especially suited to high-frequency and pulse applications since eddy current effects are reduced to almost negligible proportions. In metallic cores power loss occurs at high frequencies because eddy currents produce local magnetic fields which slow down the motion of the domain walls. This effect makes itself felt as an apparent drop in the permeability at high frequencies. Even cores made of 0.001-in tape or finely powdered Rhometal exhibit a serious drop in permeability at frequencies above about 100 kc/s. Eddy current damping is almost completely absent in ferrites. Residual damping effects occur in them, due perhaps to changes in the position of impurity atoms as the domain walls move, but they are effective at rather high frequencies. There is a special kind of power loss which assumes importance in ferrites at frequencies higher than 1-1,000 Mc/s, depending on the particular ferrite. This is due to the phenomenon known as natural ferromagnetic resonance. When a spinning electron, which contributes to spontaneous magnetization, is deflected from an easy direction it precesses. That is, its axis of spin rotates about the easy direction just as a gyroscope precesses when disturbed. The precessional frequency is determined by the anisotropy constant K—or by other factors which may, in some materials, determine the easy direction. If a field, which alternates at a frequency close to the precessional frequency, is applied to a specimen, power will be absorbed from the field to provide the precessional energy. This is progressively communicated to the lattice, where it appears as heat. The higher the anisotropy constant K, the higher the frequency at which resonance absorption sets in. On the other hand, as has been pointed out earlier, the higher K the smaller the permeability, whether it be due to wall motion or domain rotation. The magnitudes of K and λ of Ferroxcube B can be varied by adjusting the relative proportions of the nickel and zinc oxides in the initial mix. Ferroxcube B materials have thus been made covering the range of initial susceptibilities from 20 up to 650. The frequencies up to which these materials may usefully be employed in tuned applications range therefore, in the reverse order, from about 100 Mc/s down to 1 Mc/s. Ferroxcube A materials have lower K and λ therefore higher initial permeabilities of about 1,000, but lower limiting frequencies at about 0.5 Mc/s for tuned applications. Compared with the permeabilities of nickel-irons in bulk, ferrite permeabilities are very low, but for the high-frequency applications for which the ferrites are mainly intended, metallic cores would have to be used in finely divided powdered form and then their permeabilities are usually much less than 100. Saturation inductions for Ferroxcubes vary between 2,000 and 4,000 gauss, and their coercivities are between 1 and 5 oersteds. Apart from applications in coils and transformers at radio and video frequencies there are a number of special uses of ferrites especially in microwave or radar techniques. Because they have high electrical resistivities their magnetic-flux-concentrating properties (μ greater than one) can be employed in the construction of aerials which are considerably smaller than conventional types.

(To be concluded)

Technical Notebook

Split-Information Speech transmission system described by F. de Jager and J. A. Greefkes in *Philips Technical Review* Vol. 19, No. 3, is intended for conditions where it is essential to maintain intelligibility at very high noise levels. It is known as "Frena", from the fact that the speech information is split into frequency and amplitude signals, which are transmitted in separate channels then recombined at the receiver. The idea is based on Licklider's experiments on "infinitely clipped" speech waveforms which showed that intelligibility is conveyed mainly by the zero-crossings or frequency information and not so much by the amplitude information. A clipped waveform transmitted at the maximum possible amplitude permits a high noise level without detriment to the frequency information (as in f.m.) while the amplitude component or "envelope" of the speech waveform, being of low frequency, can be transmitted in a narrow bandwidth channel, which, of course, restricts the noise power. In "Frena" the speech waveform (a) is made to modulated a carrier and one of the resultant sidebands (b) is taken for clipping as shown at (c). This gives a finer gradation in displacements of zero crossings than would be obtained by clipping the original a.f. signal and results in better quality. At the same time the envelope of the single-sideband signal (b) is obtained by detection. The frequency signal is transmitted in a 3-kc/s bandwidth, which turns (c) into the almost sinusoidal waveform (d) while the envelope signal is transmitted in a 100-c/s bandwidth. An even greater noise level is permissible if the amplitude signal is coded into an on-off type of switching waveform as shown in the lower diagram. The original envelope (e) is first squared (f) and the intervals are transmitted as short wave trains (g). On reception the signal is deformed by noise (h) but is squared again to receive (f), which is rounded off as at (i) to give a signal for switching on and off the frequency channel at the appropriate instants. This on-off coding has the advantage of suppressing the "packets" of



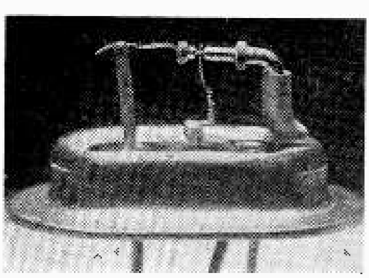
noise which confuse intelligibility by occurring between words or phonemes. It permits a noise power as high as 40% of the signal power, i.e., a signal/noise ratio of only 4dB.

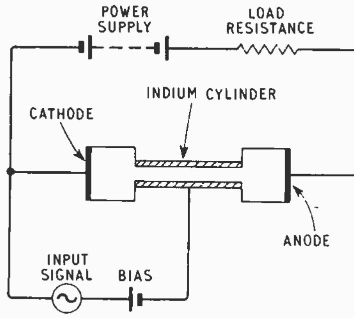
Ferroelectric Switching Devices of the multi-position type are discussed by R. Alonso and T. Conley in D.S.I.R. report PB120239, which deals in general with applications of ferroelectric materials, such as barium titanate, in digital computers.

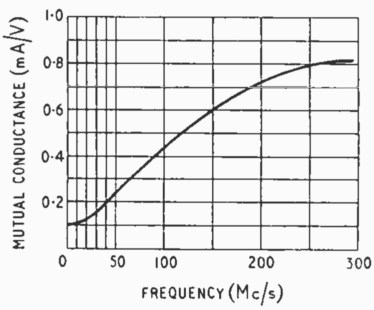
Low-Background G-M Tube with an extremely low rate of count in the absence of the test specimen has been developed by G.E.C. for measuring minute amounts of radioactivity. The length of the anode wire has been kept to a minimum to reduce extraneous response and the materials used have been selected as being free from radioactive contaminants. Background responses as low as 0.4 counts per minute have been obtained using a shielded enclosure and an anti-coincidence system to reduce stray radiation.

Total Differential Feedback.—The amount of negative feedback which can be applied to a multi-stage amplifier is limited by considerations of stability. In multi-channel carrier telephone systems in which the signals pass through many repeaters it is often desirable to apply very large amounts of feedback to keep the total distortion within bounds. A method of squaring the amount of feedback (i.e. increasing it from A dB to 2A dB) without affecting stability margins is described by J. H. C. Davis in the February issue of *Electronic and Radio Engineer.* The signal fed back from the amplifier output is compared with the input signal, and the difference between these (which contains the distortion products) is amplified in a second amplifier and combined with the output of the first so as to cancel the distortion. A useful feature of the arrangement, which is similar to two amplifiers in parallel, is that if one path fails the other remains operative. The gain can be made to remain nearly the same under this condition, though the distortion is increased.

The Tecnetron, the new French v.h.f. semiconductor device mentioned in our February issue (p. 82) is illustrated below. It consists of a

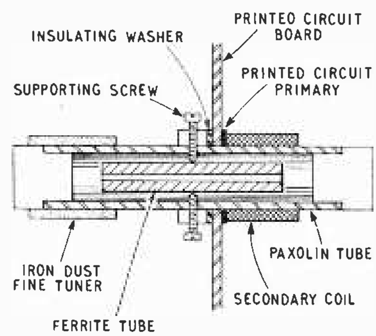






2-mm rod of n-type germanium, 0.5mm in diameter, with a narrow neck in the middle surrounded by a ring of indium. A supply voltage of about 50V sends through the rod a current, which is controlled, as shown in the circuit diagram, by a signal voltage applied to the negatively biased centre electrode. The resultant fluctuations of current then produce an amplified version of the signal voltage across the resistance load. The mechanism of current control is comparable with the field-effect transistor in that a voltage (negative in this case) applied to the indium ring produces an electric field which deflects the current carriers (electrons here) towards the axis of the rod. Thus the conducting cross-section, and hence the resistance of the rod, is varied according to the applied signal voltage. But the device differs from the field-effect transistor in two ways: it does not have an alloyed junction between the centre electrode and the germanium but a surface barrier; and it uses a cylindrical centre electrode instead of two plane electrodes. The importance of the cylindrical structure of the centre electrode is that the variation of conducting cross-section with signal voltage results in a corresponding variation of the capacitance between this conducting region and the indium ring. This effect, in conjunction with the resistance variation which occurs at the same time, is responsible for the Tecnetron's high frequency performance. The anode current/voltage characteristic curves are similar to those of a pentode valve, and in fact the device operates very effectively, like the pentode, as a voltage amplifier. The input resistance is of the order of megohms (capacitance about 0.2pF), while the output impedance is generally greater than 1 MΩ. Mutual conductance increases with frequency as shown in the curve. Experimental results show that a gain of 22dB is obtainable at 110Mc/s or 16dB at 200 Mc/s. As for power output, it is said that 30mW can be achieved in Class A operation at 500 Mc/s.

Printed Filter Coils are used in a novel method of mounting magnetostrictive ferrite filters devised by Cossor Radar and Electronics. Mechanical filters and resonators based on the natural period of vibration of nickel rods, mechanically energized by the magnetostriction effect, have been used for some time and are notable for their high Q and sharp frequency discrimination. More recently ferrite rods have been used in place of nickel to reduce the eddy current losses. The Cossor filter actually consists of a tube of nickel zinc ferrite (see sketch) supported at its centre by three screws symmetrically placed in a brass ring (which is split to avoid the effect of a shorted turn). The input coil for energizing the tube is a single printed turn, while the output coil is an orthodox wire-wound one of 200 turns. An initial permanent magnetic polarization is given to the ferrite tube by passing a large current along a wire passed through its



centre. This circumferential polarization, together with the alternating axial field produced by the input coil, sets up a spiral alternating stress in the tube. If the frequency of the input signal, and hence the spiral stress frequency, coincides with the natural torsional resonant frequency, then the ferrite vibrates and so induces an alternating voltage in the output coil. The bandwidth of a single filter is very small (7c/s), so a whole bank of them is necessary to cover a larger band, and this is where the printed-circuit type of mounting proves useful. A double-sided printed circuit board is [illegible] to support the Paxolin tubes con[illegible] the ferrite elements. The [illegible] turn primaries, all in serie[illegible] [illegible]re printed on one side, while condu[illegible]ors for connecting the output coils to an edge connector are on the other side. Final tuning is by iron dust cores.

Mechanics of Electronics

By W. D. CUSSINS, M.A., Ph.D.(Cantab.)

PRACTICAL TRANSLATIONS OF CIRCUIT DIAGRAMS; HOUSING THE EQUIPMENT

THERE is a continuous succession of articles in the technical press on useful apparatus for the electronic engineer to make, but hardly ever any details of layout and mechanical design. Nevertheless, attention to these two aspects can make all the difference between an amateurish-looking hookup and a professional instrument. With thought this improvement can be achieved by the use of very little equipment, whilst the extra effort involved pays handsome dividends in the form of improved external appearance, neater, more compact layout and greater accessibility.

The secret of success is a methodical approach.

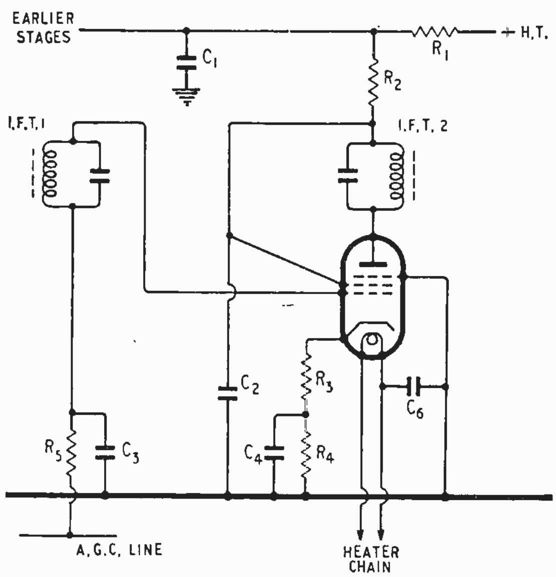


Fig. 1. Circuit diagram of typical i.f. stage.

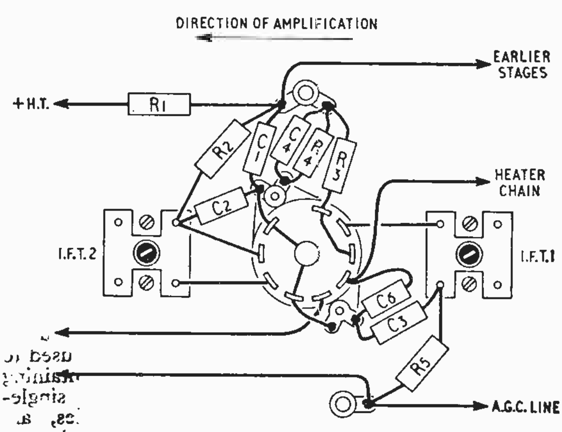


Fig. 2. Practical layout for the circuit in Fig. 1.

It is well worth while keeping a scrap book of ideas; such as component layout, chassis design, external finish, etc. If this is done there is less tendency to take snap decisions about these matters which are later regretted. An idea which appeals when it is recorded in the scrapbook may not appear so good when examined a week later, and after a month may be thrown away because of some overwhelming disadvantage, which only became obvious after a prolonged period of sub-conscious thought.

Thus, when one decides to build a new piece of apparatus, a perusal of the scrapbook will yield a fund of ideas upon which the design can be based. However, before a hand is raised to beat a piece of metal into shape the whole layout should be finalized. This applies not only to the mechanical side but also to the electrical. If this is not possible because the apparatus is to be specially designed, rather than made up from a proved design, it is necessary to make a mock-up to finalize the electrical design before the layout of the apparatus can be decided. It may take longer but the decision to do it will never be regretted.

Component Layout.—It is difficult to give useful generalizations concerning component layout but perhaps details of two entirely different types of circuit layout will provide a few useful ideas.

Fig. 1 shows a generalized i.f. stage, from which most others can be developed by omitting or adding various components. Thus, if a layout can be developed for this it will have a wide application. The main design criterion here is minimum length of leads, even to the detriment of accessibility and ease of construction. They must not suffer unnecessarily and Fig. 2 shows a reasonable compromise which has proved quite satisfactory in practice. Care has been taken to orientate the valve holder to give the shortest possible leads into the coil cans. The heater leads, h.t. and a.g.c. lines are all arranged so that they will easily link up with previous and later stages.

A completely different type of circuit is illustrated in Fig. 3. It is the driver and output stage of a push-pull amplifier, drawn somewhat unconventionally in order to show up its electrical symmetry. This obviously cries out for imaginative treatment when it comes to layout. In this type of circuit there is usually sufficient space to lay out the components on tag-strip screwed to the chassis under the iron-cored components. A little study results in the layout shown in Fig. 4. It is neat, makes all components accessible and enables the circuitry to be followed easily.

A third type of layout was developed for the detector, noise limiter and audio stages of a television receiver. In a television set, chassis area is at a premium, but there is usually plenty of space to build component panels at right angles to it. A tag-board as shown in Fig. 5 can be used. This type of board is very useful for all electronic circuitry where there is a high density of components. For instance, one long board was used to carry all the components necessary for the video, sync-separator and both time-bases of a television receiver except the pre-set and iron-cored ones.

These basic layouts have been used for all apparatus built by the author in the past few years and have proved highly satisfactory. Other people may prefer variations but the basic idea of planned component layout is very important and saves a great deal of time when fault finding.

Mechanical Design.—Having suggested various methods of laying out the components in a piece of equipment let us see how the chassis to hold them can best be designed and built. But first of all let us digress to see what tools will be required over and above the normal mechanical workshop selection. There are two essentials for a neat job: a guillotine and a bender. Small versions of each can be bought quite cheaply and over the years will pay for themselves many times. A third, which is essential to the person who does a lot of work, is a universal bolster press with a varied selection of punches (circular and rectangular) and a louvre tool. A cheap alternative to this is a hand-operated lever punch, which will make holes up to ½in diameter, and a set of chassis cutters. The great advantage of punches over drills is that they produce clean holes without burrs. Using these tools and your ingenuity it is possible to work near miracles.

And now to the chassis itself. The first thing to remember is the size of the sheet of metal from which it will be cut. It is possible to get many more pieces 17¾in wide than 19in wide from a 3-ft wide sheet. Make sure, therefore, that the design will cut economically from the available sheets. Forget about the beautiful effects manufacturers get with their expensive press tools and try to imagine how near it is possible to get with a bender. By way of illustration consider the box for the portable amplifier (Fig. 6) and the rack (Fig. 8) and power amplifier chassis (Fig. 9) for mounting in it.

The portable amplifier box was made in five parts as shown, the two ends being identical. The top slides inside the vertical lips of the ends, but rests on the horizontal ones. To allow this to occur the ends are notched as in Fig. 7 (a) so that when the sheet is bent along the dotted line the result is as shown in Fig. 7 (c). If a press tool is not available to notch the corners it can be done neatly by first drilling a small hole and then cutting with a pair of tin snips (see Fig. 7 (b)). Cutting the corners farther back than the bend lines is necessary to allow the top to pass through the slot, but it is a useful dodge to adopt at all times to enhance the appearance of the closed box. Another application of the same principle is shown in Figs. 7(d) and 7(e). The ends were attached to the main chassis with a $\frac{1}{16}$-in clearance. The advantage of this is threefold. There is an inevitable bend radius of the end lips which prevents the lip and chassis sides from lying flat unless the spacing exists. It allows the top, which is the same width as the chassis, to slide easily into position. It also leaves slots into which the lips on the bottom fit. These latter are multi-purpose; stiffening the bottom, giving it a smooth surface (note the ends do not project as far down as the lower edge of the chassis) and preventing the ends from bowing inwards. This box is very easy to construct and very strong when made. However, before attempting to make one, try a few sample bends with the sheet metal you are to use to get an idea of the allowance to be made for bend radius. Do not forget the thickness of the metal in your calculations.

Now to something rather more ambitious; or so it would appear at first sight, namely, the rack. The framework is of 1½in × $\frac{3}{16}$in angle iron, with

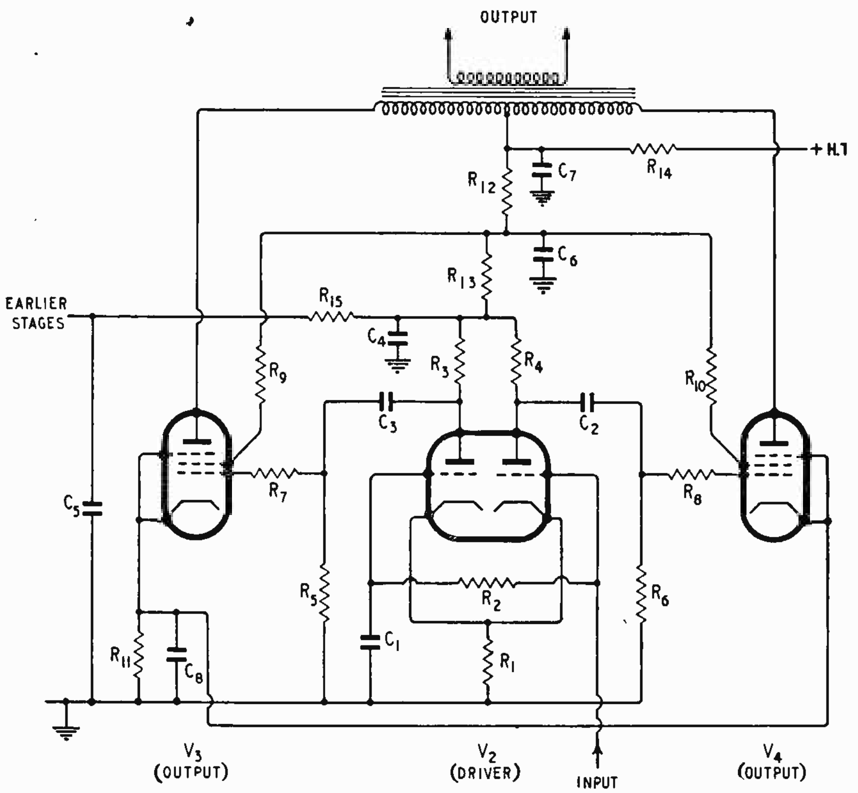


Fig. 3. Driver and push-pull output stages drawn to emphasize the symmetry of the circuit.

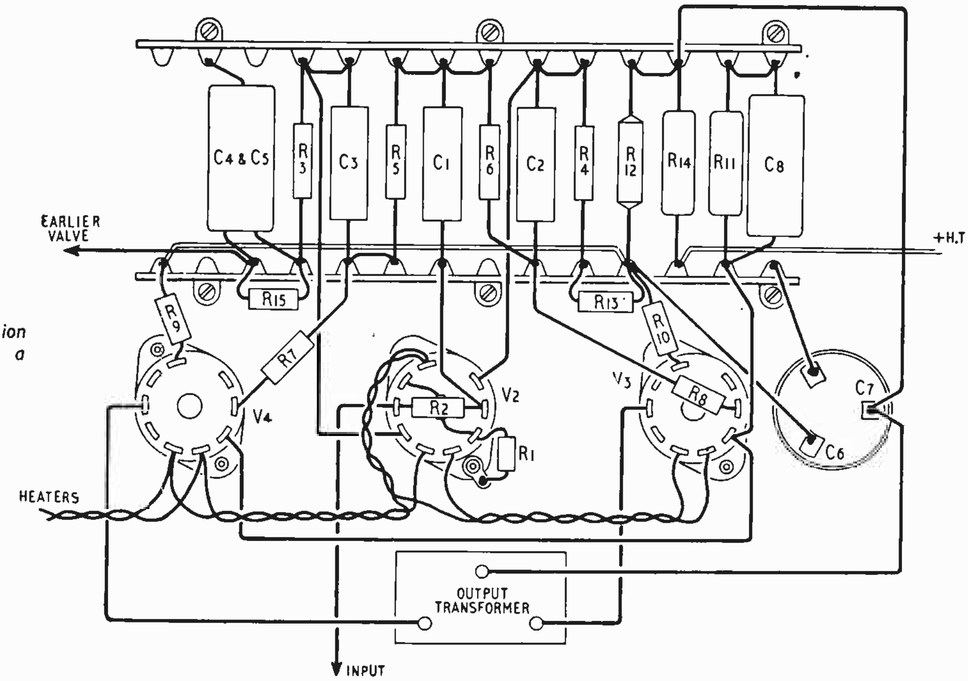


Fig. 4. Translation of Fig. 3 into a practical form.

some rather more substantial channel-section for feet. All the pieces are cut to size and shape and then electrically welded together. In the absence of a welding plant, there are plenty of small engineering firms who will do it quite cheaply, as it is a very speedy process. The side and top covers are designed so that there is adequate ventilation through holes in the cover plates. With the framework painted black and the cover plates and front panels stove-enamelled grey the result is very impressive but, in fact, very little equipment was involved in making it. The power amplifier chassis (Fig. 9) shows how a quite complicated shape is built up from simple pieces. In cases like this, decide what is the best chassis layout and then try to imagine how it can be constructed, using the tools at your disposal.

The amateur's favourite method of joining chassis parts together is to use nuts and bolts. Their use, however, is to be discouraged. For things which are to be permanently connected, riveting is far better and cheaper. A little practice in the use of aluminium rivets will soon lead to proficiency. An alternative is to use self-tapping screws, which can also be used in positions where they may occasionally have to be removed. Where screws are necessary, it is preferable to use tapped holes or captive nuts with them.

If more than one-off is desired, it is necessary to make a template and mark off from that. This is best done by cutting the template to size and marking the positions of all the holes and bends on it. Then drill small holes at all these points, place the blanks underneath and centre-punch through. This is best done on a marking-out board consisting of a sheet of plywood with two strips of angle iron screwed to it at right angles. If only three or four are required, the template can be made from the same material as the chassis and when the latter have been centre-punched they can all be turned into finished articles. For larger numbers a piece of high-grade sheet steel about 20 gauge is preferable.

Finish.—To conceive and construct a small masterpiece of electronic equipment is insufficient unless attention is paid to external finish. This adds little to the cost, but greatly to the appeal. Remember, friends will see only the outside and make their

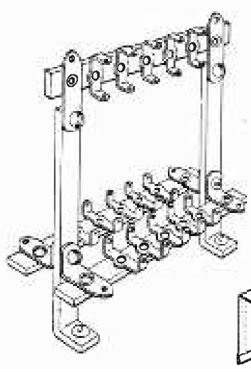


Fig. 5. Group-board assembly for mounting components vertical to the chassis.

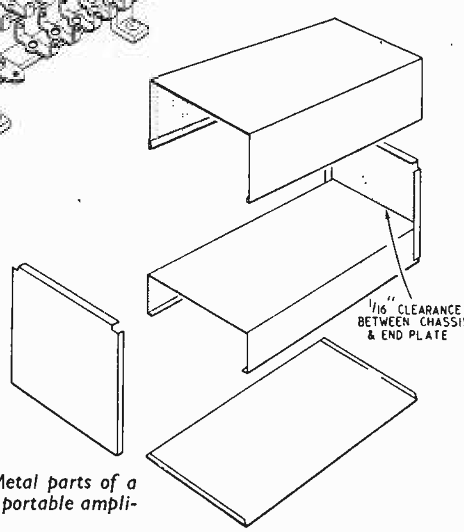
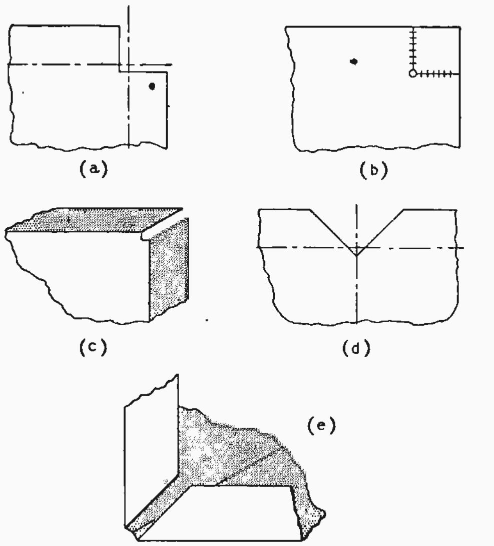


Fig. 6. Metal parts of a box for a portable amplifier.



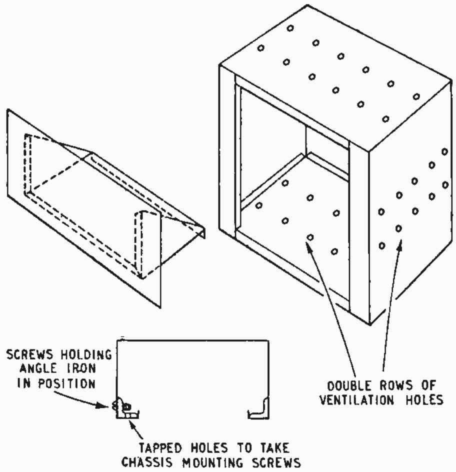


Fig. 10. Metal cabinet for housing two equipment chassis one above the other.

Fig. 7. Details of the corners of the box shown in Fig. 6.

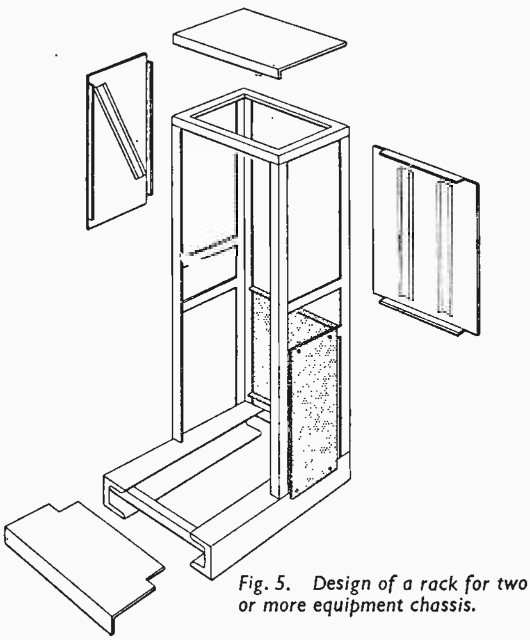


Fig. 5. Design of a rack for two or more equipment chassis.

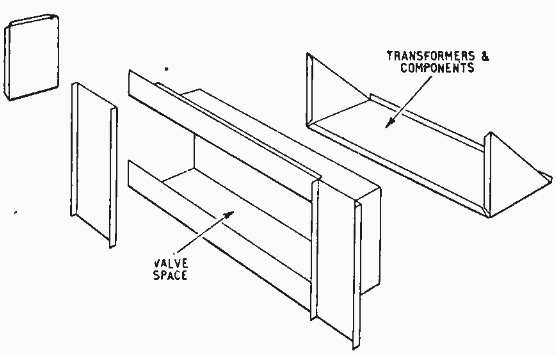


Fig. 9. Details of a power amplifier chassis.

judgments therefrom. Bare metal and stuck-on bits of paper are taboo. It is not difficult to get the external surfaces cellulose sprayed or even stove enamelled, and several types of transfer are readily available.

For really special pieces of gear, lettering can be engraved instead of transferred and chromium-plated handles and screws used. It is, of course, possible to buy professionally made cabinets or kits, but to use them is almost an admission of defeat by the proud engineer. Here, again, a scrapbook or folder of pamphlets of these odds and ends is very useful, otherwise when something is required, although you know an item is available, you cannot remember who supplies it.

Up to now most, if not all, of the suggestions for improving the breed have involved extra expenditure, and unless economies can be made in other directions, no one is likely to heed them. The obvious one is in the purchase of materials.

As with all stores, the ideal is to achieve the maximum usefulness with the minimum of stock. This means standardization and has the advantage that, with less choice, it is easier to choose. Let us examine a few ways in which this can be achieved. Keep the gauges of metal used down to a minimum; say two, one for chassis, the other for front panels. So far as screws are concerned, standardize on one type of head (cheese head is suggested as being the most useful), the usual even-numbered B.A. sizes and a minimum number of lengths. Most types of valve are now produced with a B9A base, so use this whenever possible. Make sure that all resistors of a particular wattage are of the same appearance and similarly with capacitors. Nothing looks more amateurish than a mixture of different resistors, ceramic, insulated and uninsulated with radial or axial wire ends.

The same ideas should also be applied to the boxes in which the equipment is housed. Almost every piece of gear consists basically of two parts, a power pack and the main equipment. Power packs take much the same form and to a large extent are interchangeable; so why not use a cabinet which will take two chassis connected by a multi-wire cable, one containing the power pack, the other the specialized item of electronic equipment. This has the advantage that several containers (and power packs) can be made at a time, which is much quicker than making a succession of one-offs. A simple practical layout is shown in Fig. 10. The box consists of a single sheet of aluminium bent as illustrated with angle-iron screwed in position down the sides (this is then drilled and tapped along the front edge to act as screw fixing for the chassis). The top and bottom, which are identical, are then screwed into position and it is now ready to house the two chassis. Ventilation holes and rubber feet are added as desired.

Standardization can also be applied to the circuitry adopted. Consider, for example, the audio engineer who is called upon to build a succession of specialized equipments. All of them will probably contain a tone control network and a low-noise level microphone stage. Suitable circuitry can be developed for each purpose and then used on all possible occasions. This saves time in design and promotes reliability. To chop and change designs every time a new development is announced is foolhardy. Note them, study their pros and cons, but do not incorporate them in any permanent apparatus until a mock-up has proved their substantial advantage over the "old faithful."

Summary.—This article has attempted to show how, with a few extra tools and a lot of ingenuity, the standard of mechanical design by the amateur and semi-professional electronic engineer can be improved. Appearance, layout and accessibility are important factors in all apparatus and a little time spent in considering them initially will be amply repaid during the gear's life. Do not be afraid to copy the professional, but branch out and be original if, after consideration, circumstances warrant a new approach.

Suppressing Television "Bright Spot"

Inexpensive System for Protecting Receiver Screens

By E. MOSTON KENNY*

A DISTURBING feature of many television receivers is the intense stationary spot which appears on the tube immediately after switching off the receiver. Apart from the visual annoyance, the continued application of this intense spot to the same position on the tube can subsequently result in an ion burn on the screen.

The fact that a spot remains on the tube after switching off is due to: (a) the almost immediate collapse of the scanning circuits when the h.t. is switched off, and (b) the discharge time of the tube capacitance or e.h.t. capacitors. As e.h.t. is available for the anode of the tube, and its heater is still warm, electron emission continues, producing an unscanned beam.

Various methods can be used to suppress or deflect the bright spot. One of them is a special brilliance control now available† which suppresses the bright spot at the moment of switching off, the essential feature of the scheme being that the brilliance control should operate the "on/off" switch of the receiver.

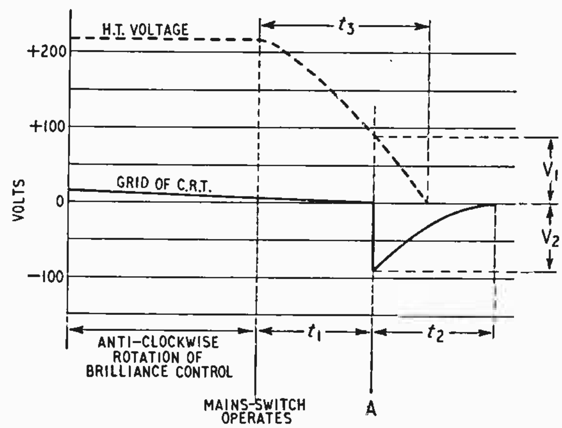


Fig. 2. Voltage on the grid of the c.r. tube as the brilliance/on-off control is turned off.

* Morganite Resistors, Ltd.
† Morganite type ABS control. Patent Application No. 10259/57.

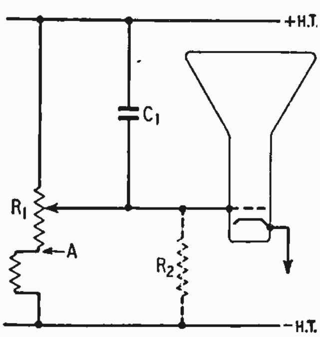
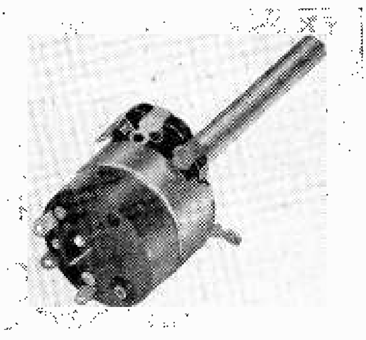


Fig. 1. Suppression circuit using the new brilliance control.

The principle of operation is as follows. Referring to Fig. 1, R_1 is the brilliance control. In the process of switching off, the slider is brought towards h.t. negative, reducing the brilliance of the tube. At point A, the "on/off" switch is turned "off" and a short interval of time afterwards the slider becomes open circuit to the resistance track. At that moment the grid of the tube is swung negatively and as a result the bright spot is suppressed.

Referring now to Fig. 2, the voltage applied to



The new combined brilliance control and on-off switch.

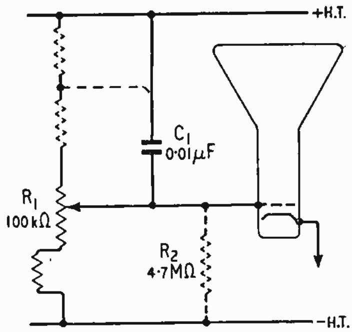


Fig. 3. Practical form of Fig. 1 with circuit values.

the grid of the c.r. tube is shown by the heavy line and the main h.t. voltage by the broken line. On switching off, the main h.t. commences to decay over a period of time t_3, but at a point some time after the commencement of this period the bottom end of C_1 becomes open circuit. By virtue of opposite charge this point swings negative to a voltage (V_2) equal to the h.t. decay voltage (V_1) but opposite in polarity, thereby cutting off the tube grid. The receiver is now in the "off" position, and the grid of the tube will slowly return to zero volts (h.t. negative) on a time constant (t_2) controlled by C_1 and R_2. As the receiver should not normally be switched on immediately after switching off, the time t_2 can be of the order of minutes. R_2 (if fitted) should be fairly high, of the order of five or ten times R_1.

A practical circuit is shown in Fig. 3. The values are suitable for an h.t. supply with a decay time of 0.5 seconds. The negative voltage applied to the grid of the c.r. tube can be reduced, if required, by taking the h.t. end of C_1 to a lower point on the potential divider chain as shown by the dotted connection.

B.B.C. STATISTICS

AS always, the "B.B.C. Handbook"* is a veritable mine of information on the organization and administration of the Corporation's sound and television services. The following few facts and figures have been culled from the 1958 Handbook.

Although the v.h.f. sound broadcasting service now covers over 84 per cent of the population and will increase to 96 per cent by the end of 1958, there were only three-quarters of a million v.h.f. sets in use last autumn.

There are still some 16 million adults in the United Kingdom without television receivers.

Of the B.B.C.'s staff of 15,242, 4,200 are engaged exclusively on work for the television service and 3,250 on technical engineering duties.

Seventy-five per cent of all B.B.C. recordings are now on tape.

Crediting £2 from each £3 combined sound and television licence to the television service, and proportioning the Treasury and Post Office deductions *pro rata*, the income from licences in the year ended last March was as follows. (The additional £1 excise duty on television licences is also retained by the Treasury.)

	Sound	Television	Total
B.B.C.	12,115,948	11,674,260	23,790,208
Treasury	1 400,117	1,349,883	2,750,000
Post Office	974,626	939,658	1,914,284
Gross licence revenue ...	£14,490,691	£13,963,801	£28,454,492

Of the £9.1M spent in operating the television service, £4.3M was on programmes and £3.5M on engineering. Of the £11.6M on sound broadcasting, £6.3M was spent on programmes and £2.7M on engineering.

Rental paid to the Post Office for lines during the year ended last March totalled over £1M. Two-thirds of this was for links for the television service.

The cost of the television service increased by 21.7 per cent. The cost per hour of transmitting programmes rose from £2,675 to £3,256. Home sound services increased by 6.5 per cent to £575 per hour.

* "B.B.C. Handbook, 1958," 288 pages, 5s.

Total number of programme hours in the Home sound services for the year covered by the Handbook was 20,120, a slight decrease on the previous year. Transmission time in the television service increased by 165 hours to 2,794 hours, and in the external services by 506 hours to 29,561 hours.

TV Tower Tests

TESTS using reaction-type rockets were carried out recently on the completed Crystal Palace television tower in order to find its natural frequency of vibration and the structure's capacity for damping out such vibration. Air flow within a certain range of wind speeds can incite rhythmic lateral movement of a structure of this kind causing it to deflect as a vertical cantilever. Should this motion coincide with the natural frequency of vibration of the structure, or its harmonics, and the controlled damping be inadequate, it could lead to the complete collapse of the tower.

A total lateral thrust of about 2.14 tons was applied to the 450-ton tower by firing 6 rockets fixed at the 630-ft level and this produced an oscillation of 8in each side of the vertical.

Instrument recordings are being analysed by the N.P.L. and it is expected that the results of the tests, believed to be the first of their kind on a high tower, will prove of great value not only in the study of the Crystal Palace's tower reaction to wind forces, but also in the design of similar structures.

B. I. Callender's Construction Co., who designed and built this 708-ft self-supporting tower, have produced an interesting film called "The Phœnix Tower." It traces the design and construction of the tower from the site excavation through the varying processes in the works and during erection to the installation of the u.h.f. experimental aerial which surmounts it. The 40-minute film, which incidentally does not include any shots of the tests referred to above, can be borrowed from B.I.C.C., 30 Leicester Square, London, W.C.2.

Forward Projection in the Home

Converting a Rear-Projection Television Chassis

By A. G. TUCKER

FOR various reasons projection television for the home has not been a success, either here or in the United States. When manufacturers were faced with the demand for bigger pictures a few tentatively tried some rear-projection models, but gradually the trend has swung over to larger and larger cathode-ray tubes for direct viewing. To-day there are only a few projection models available for home use, and I believe all of these are rear-projection types.

The objections which have been raised against this type of receiver may be summarized as follows:—

(1) An insufficiently brilliant picture, necessitating viewing in a nearly dark room.

(2) In the case of forward projection, a large and unwieldy console standing in the centre of the room, with mains and aerial leads lying across the floor.

(3) Rather poor e.h.t. regulation, with consequent focus instability with changing picture content.

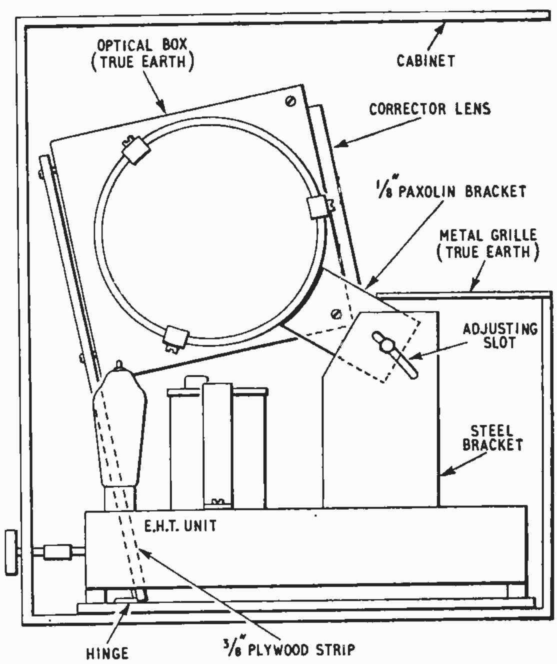
(4) Complicated circuitry and less reliability.

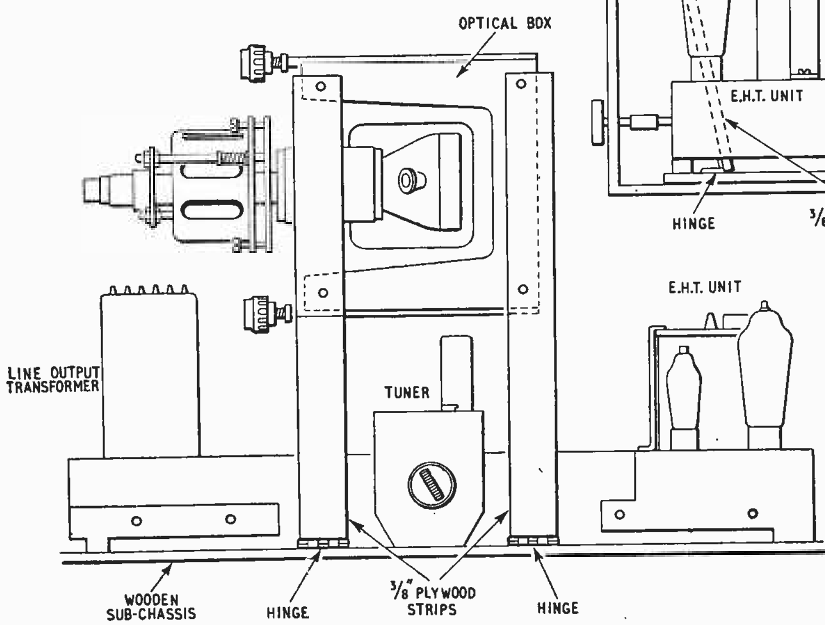
It is the purpose of this article to show that all these objections can be overcome, partly or wholly, in the case of forward projection in a normal-sized living room.

Dealing with the objections in order, first of all it must be remembered that nearly all commercial forward-projection receivers are designed specifically for use in schools, hospitals, etc., where an audience of perhaps thirty or forty people has to be catered for. This necessitates a large, sometimes flat screen, usually 4ft × 3ft, situated fairly high on the wall—a position which will give maximum reflection of any ambient lighting in the room.

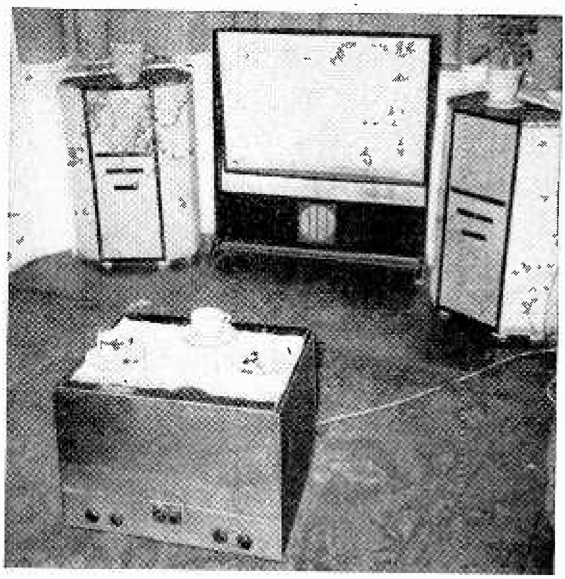
At home a different procedure may be adopted. In the writer's case the screen is mounted in a wooden framework which gives adjustable height and tilt. The centre of the screen is only 26in from the floor and it is tilted at about 10° from the vertical. The screen size of 30in × 22in is considerably larger than the largest direct-view picture obtainable, and is just about optimum for the room size of 14ft × 12ft.

The room lighting for normal viewing at present consists of three 100-watt lamps reflecting from the ceiling. This gives adequate illumination, at the same time permitting a reasonably good picture to be enjoyed. On special occasions—for example, when the family wishes to sit down and enjoy a





Method of mounting the optical box on the chassis of the receiver.

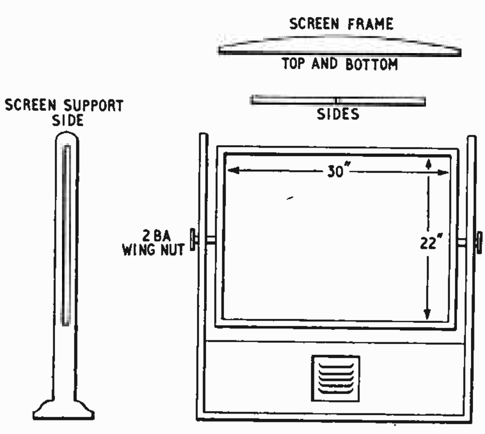


Arrangement of the modified projection set and screen in the author's living-room.

good play—a small standard lamp is used, when the performance can only be compared with a good cinema picture. By making the screen slightly concave in a horizontal direction a wide angle of viewing is obtained, and its forward tilt and low position give minimum reflection of ambient lighting. Activated aluminium screens of similar design may be obtained from P.A.M., Ltd., of Guildford, Surrey.

Compact Console

Coming now to objection (2), it is quite possible to make a forward projection console reasonably small. The particular one in use by the writer at the moment is built around a Philips 704A chassis and measures only 15in high by 21in wide by 18in front to back. By fitting the optical box at the rear of the chassis, i.e., farthest from the screen, the console itself is brought nearer to the screen and farther from the centre of the room. The main reason for making the console as low as possible is to enable the picture to be viewed from normal armchair height over the top of it, i.e., directly in front of the screen where the picture is at its brightest. In its position about 5ft from the screen (64in from the corrector plate to screen) the console also comes in useful as a coffee table.



Constructional details of the screen with the loudspeaker built in below.

The best way to overcome the difficulty of untidy leads is to run aerial, mains and speaker leads in one piece of sleeving from the console to two sockets on the skirting board near the screen—one for mains and one from the aerial and speaker. It will be found far better to place the loudspeaker with the screen rather than in the console, partly to avoid the "disembodied voice" effect and partly to save precious space in the console. Two leads have to be run to the console anyway, so that the extra leads for the speaker are no problem.

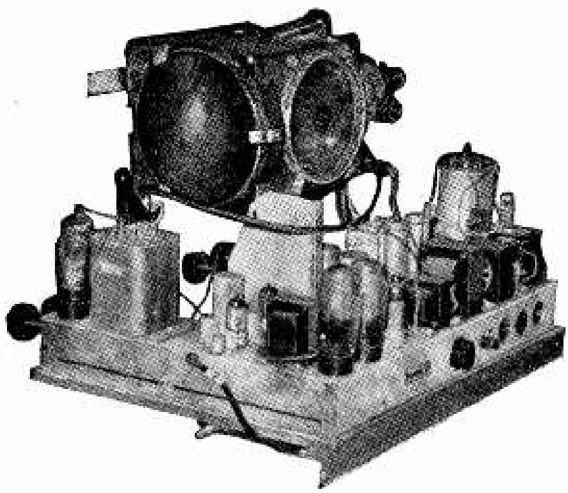
With regard to objection (3), this problem solves itself to a certain extent with forward projection. Owing to the greater light transfer efficiency as compared with rear projection, the beam current of the c.r.t. need not be so high for a bright picture and consequently the e.h.t. generator need not be driven so hard. The regulation of any of the commercial rear-projection models will usually be quite adequate, but should greater focus stability be desired there are various ways of doing this which should be well within the ingenuity of *Wireless World* readers. One solution is to introduce a certain amount of vision a.g.c. which is based on the peak white in the picture. This degrades the contrast values to a certain extent but gives a good stable picture.

The fourth objection, of complicated circuitry and unreliability, is simply not true. The only additions in a projection receiver are the e.h.t. generator and a safety circuit which blacks out the beam to prevent burning of the screen if either timebase should fail. In the writer's experience these sets give very little trouble and when they do the servicing is usually straightforward.

At the present time there are many old rear-projection sets on the second-hand market and the only major modification necessary for conversion to forward projection is the changing of the corrector plate on the Mullard optical box to give a throw of 64 inches. I understand that this service can now be done through any Philips dealer by M. Bender (Northern), Ltd., of Newcastle-upon-Tyne.

It is hardly possible to give detailed instructions for the mounting of the optical box as this will depend entirely on the particular chassis chosen for conversion. From the point of view of ease of servicing and initial setting-up, etc., it will be found better to mount the box directly on the chassis rather than fix it to the interior of the cabinet. It must be rigid and have some means of varying the angle of throw in a vertical direction through about 5-10°.

The Philips series 600A, 1800A and 704A receivers, being very compact, are particularly suitable for conversion, and in these the optical box may be mounted approximately in its original position, i.e., next to the e.h.t. unit. Two pieces of ⅜in plywood 1¼in wide by 12in long are bolted to the back of the box and have their lower ends joined to the wooden sub-chassis by hinges. The front of the box is bolted to two steel brackets fitted to the main chassis at right angles to the box. The



The modified receiver with the optical box mounted on the chassis.

bolts connecting the box to these brackets run into slots in the brackets to allow the vertical angle to be varied. Incidentally, with this method of mounting it will be found that a turret tuner will just fit under the box, with its station selector knob nicely in line with the other controls. It must also be remembered that these chassis are live, and suitable precautions should be taken to ensure that no part of the chassis is accessible from outside the cabinet.

It does not come within the scope of this article to deal with circuitry but merely to give suggestions for the general arrangement of the console and screen for home use. If these suggestions are carried out I can promise that the result will be a pleasant surprise, especially to those who have only seen forward projection at exhibitions or in shops. In spite of the fact that, in theory, it is impossible to obtain a real black on a silver screen in a lighted room†, it will be found in practice that the contrast range is at least as good as a direct-view receiver. This is probably because black is only comparative in any television receiver and the extremely good highlights obtained on the silver screen make the blacks appear just that much blacker.

Better Picture Quality

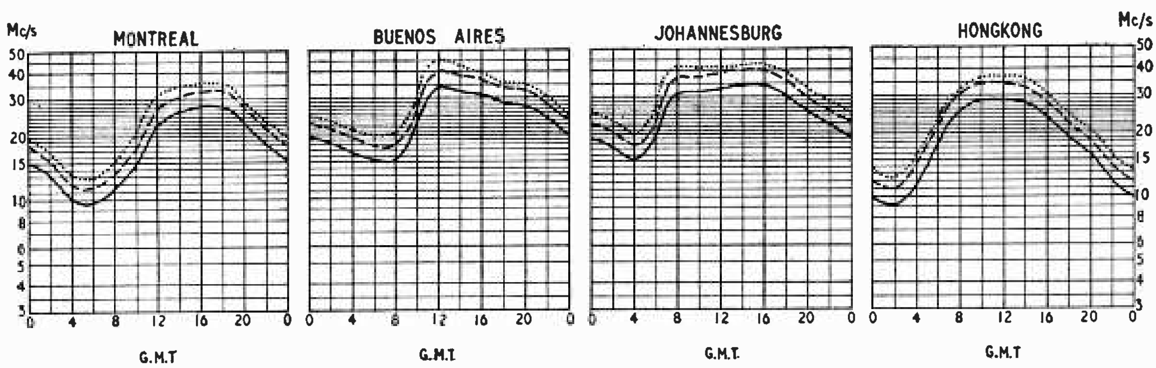
One of the main criticisms of back projection has been the "softness" associated with this type of picture. This effect is mainly due to the light scattering which cannot be avoided with even the thinnest of translucent screens but which does not occur with forward projection, where the light is beamed directly on to an opaque screen. The absence of external mirrors, which slowly lose their efficiency through the accumulation of dust, etc., is another great advantage over rear projection. It would probably be fair to say that the general tone or "goodness" of the forward-projection picture lies somewhere between that of a good rear-projection set and that of a direct-view type, with a bias toward the last-mentioned. When one considers the many other advantages of forward projection, e.g., the really big picture and the beautifully even focus, the change is certainly worth considering.

In conclusion, not the least of the advantages of forward projection is the low cost of replacing the c.r.t., which is only about one-third of the price of even a 21-in direct-view tube, and unless I have been exceptionally lucky the useful life of these projection tubes is, if anything, longer than that of their big brothers.

† "Projection Television," Letters to the Editor, December, 1957, issue.

SHORT-WAVE CONDITIONS

Prediction for March



THE full curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during March.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

·········· FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

———— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

The Magnetodynamic Pickup

Advantages of a Moving Magnet System

By C. BROWN

SOME of the most successful gramophone pickups to appear in recent years have used the electrodynamic or moving-coil principle and at least two have employed a cantilever type stylus, the advantages of which are well known. In the electrodynamic system, however, a coil of extremely fine wire with only a few turns must be used to ensure that the mass of the moving system is kept low. Even with a large magnet, the voltage induced in such a pickup is very small and a transformer is required between the pickup and any practical amplifier.

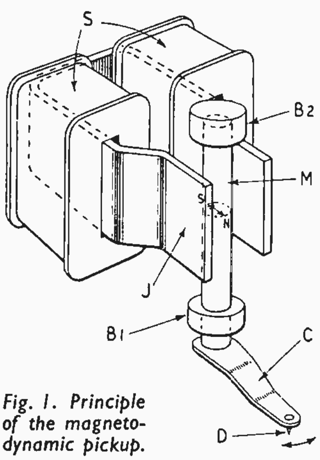


Fig. 1. Principle of the magnetodynamic pickup.

In the magnetodynamic pickup developed by Philips, the magnet and coil exchange their roles: the magnet is the moving element and the coil is fixed. A much higher sensitivity is possible than is the case with the electrodynamic system and no input transformer is needed.

The magnetic system of this pickup differs also from that employed in moving-iron (variable reluctance) pickups: in these, a part of the magnetic circuit moves, but not the magnet itself.

Design Details.—A rod-shaped permanent magnet M is located between the ends of a yoke J in which the coils S are wound (Fig. 1). This rod armature is diametrically magnetized and is held in two bushes B_1 and B_2. At the lower end, the magnet has a needle arm or cantilever C cleated to it with an aluminium collar, and the diamond tip D is fixed in a similar fashion.

The equilibrium position of the magnet coincides approximately with the position of magnetic symmetry and, clearly, any lateral movements of the stylus will produce flux alternations through the yoke and hence induce a signal voltage in the coils.

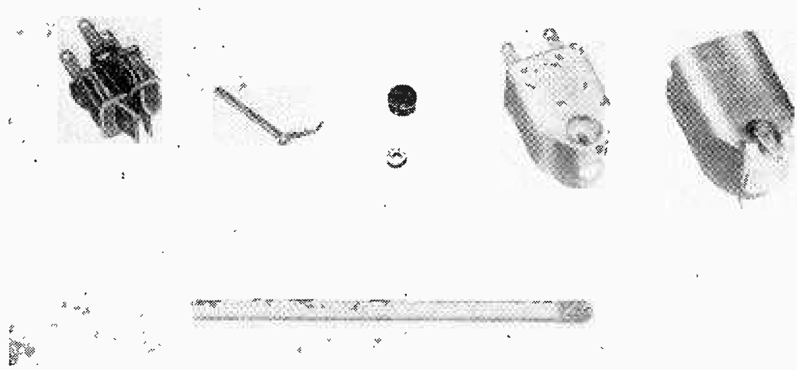
Sensitivity is high (approximately 44 mV per cm/sec) giving an output of 24 mV r.m.s. for a peak velocity of 6 cm/sec—a typical value for microgroove records. This figure, although lower than for crystal pickups, is higher than can be achieved with many electrodynamic movements using transformers. It is higher, too, than that of many pickups of the variable reluctance type.

The Moving System.—The component parts of the pickup "cartridge" are shown in Fig. 2. The most unusual of these is the magnet, and some comment on the choice of material and shape may be of interest.

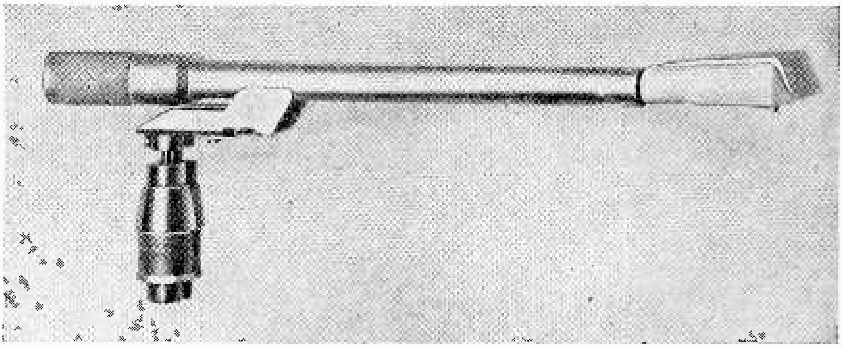
To achieve good sensitivity, the magnet flux must have as high a value as possible. The magnet should be proof against demagnetization by external fields; this necessitates a high demagnetization factor, and a "short" magnet is therefore called for. A further essential, in view of the high accelerations which will be encountered, is a small moment of inertia.

A magnet to satisfy these requirements was made possible by the development of Ferroxdure[1], a material with a high coercive force—about 1,000 oersteds in the present application. The density is low: about 4,000 kgm/m^3, compared with twice this figure for Ticonal steel. The conflicting requirements of large flux and small moment of inertia were resolved in a rod shape, 0.8 mm in diameter and with an effective length of 8 mm. The effective mass at the stylus is 2.8 mgm. The rod is made by extrusion, sintering and grinding, and is magnetized perpendicular to its axis of rotation.

Fig. 2. Component parts of the pickup. (Left to right) Yoke and coils; magnet and stylus; rubber and p.v.c. bushes; polyester block, cast around the yoke and coils; complete "cartridge". On either side of the cantilever are protecting shoulders.



This form of armature is obviously a much simpler manufacturing proposition than the electrodynamic pickup's coil of fine wire on a fragile former; it is more reliable in service and there is great consistency in performance between large numbers of pickups. Accurately dimensioned rod magnets are obtained which are easily interchangeable.



Complete pickup and arm, showing "micrometer" adjustment of playing weight.

The restoring couple for the magnet is provided by the rubber bush B_2 in Fig. 1. Damping must also be provided and this is achieved over a wide frequency range by the p.v.c. bush B_1. This damping, the effective mass and the stiffness of the movement, comprise the mechanical impedance. The bore of the p.v.c. bush is slightly greater than the magnet diameter; the magnet is pulled against the wall of the bush during use and this is found to give a suitable degree of damping. The lateral compliance obtained with this arrangement of bushes is at least 5×10^{-6} cm/dyne.

The method of supporting the armature permits movement other than rotation. In an electrodynamic system this could lead to the generation of unwanted signal voltages; at the same time it has often been found that too great a restriction on movement is liable to provoke distortion due to the introduction of resonances into the audible frequency range. In the magnetodynamic system, therefore, where in theory only one mode of armature movement can produce a signal voltage, there is an advantage in allowing freedom in more than one direction. The high degree of vertical compliance (10^{-6} cm/dyne) is, of course, important where the well known "pinch effect" is concerned.

The mechanical noise radiated from pickups having a large armature area rigidly connected to the stylus tip can be most objectionable; here again the excellent vertical compliance is beneficial and the area of the rod magnet is smaller than that of most moving coils.

The Yoke and Coils.—The yoke must have high initial permeability and Mumetal was chosen for this part. It is in the form of a strip of 2 sq mm cross-sectional area, bent to the required shape.

The magnetic induction in the yoke is very low compared with the saturation induction of the material and distortion due to saturation is impossible. Only a part of the magnet flux passes through the yoke (the remainder completes its circuit in the air).

The two coils, total impedance 5,000 ohms, form an approximately astatic system. They are wound on the arms of the yoke and this, together with the armature and bearings, is contained in a cast block of polyester resin. The whole assembly is provided with a Mumetal screen and a robust "cartridge" is thus formed, proof against tropical climates. Both the yoke and the magnetic screen are connected, via the pickup lead, to the amplifier, thus suppressing any noise due to static electricity generated by the friction between stylus and record.

The Arm.—This is straightforward in design and is equipped with a continuously variable counterweight giving a playing weight range of 0-10 gm. No springs are used. Recommended playing weight for general use is 5-6 gm, although the pickup will track satisfactorily below this on a great many records when conditions are good. The author has particularly in mind accurate levelling of the record playing equipment, to avoid unwanted lateral forces on the arm.

It is often maintained that a spring adjustment of playing weight is best because it enables a lighter arm to be used. This is true, but a light arm does not guarantee a small inertia. The case for and against has been neatly summed up by Barlow[2].

A point of some interest is that any ferrous metal can be used for the turntable in any system which incorporates the magnetodynamic pickup. This is not the case with moving coil pickups, where the large magnet would exert an appreciable force on a ferrous turntable with a consequent increase in playing weight.

Frequency Response.—In record reproduction, the upper limit of frequency response may be determined by a resonance or by a tracing loss concerned with the relative amplitudes of the stylus and recorded groove being traced[3]. So far as resonance is concerned, this may be due solely to the pickup's moving system, or it may be the compliance of the record material resonating with the effective mass at the stylus tip.

The magnetodynamic pickup's armature resonance occurs at about 26 kc/s and it is therefore, the "groove stylus" resonance, depending on record material characteristics, which imposes the upper frequency limit. This lies at 18-19 kc/s for microgroove records in the present state of the art. The output voltage of the pickup, then, is proportional to recorded velocity up to this limit. Reference was made above to a tracing loss and, this, rather than a resonance, will impose the upper frequency limit when the pickup approaches the inner grooves of the record. The effect is, unfortunately, one that is inherent in reproduction from disc records.

The low-frequency response of a pickup is usually limited by resonance, and it is generally agreed that this, since it cannot be eliminated, must be kept at as low a frequency as possible by good arm design and attention to the compliance of the armature system. If a maximum is set for armature restoring force in the interests of a low resonant frequency, it is equally true for many magnetic pickups that a certain minimum force is necessary to centre the armature in opposition to the magnetic field.

It follows that a reduced field—and signal voltage—usually accompanies low resonant frequency. These considerations apply to the magnetodynamic pickup in principle, but the very small field acting against restoring force makes possible an excellent relationship between output voltage and the compliance value quoted earlier, with a smooth response extending to 25 c/s.

Intermodulation distortion tests using 60 and 4,000 c/s tones at 4:1 ratio, gave the low figures of 0.6% at 8 cm/sec and 1.4% at 20 cm/sec recorded velocity. The figures are, of course, for pickup and record together.

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[1] Went, J. J. *Philips Technical Review.* Vol. 13, pp. 194-208. 1951-2.

[2] Barlow, D. A. *Wireless World.* June 1957.

[3] Kerstens, J. B. S. M. *Philips Technical Review.* Vol. 18, pp. 89-97. 1956-7.

Commercial Literature

Transformers for mains, audio, e.h.t. and low-voltage applications; also smoothing chokes. A comprehensive catalogue giving electrical data, physical dimensions, mechanical drawings, and a price list from Gardners Radio, Somerford, Christchurch, Hants.

Magslips; a 60-page publication dealing with their history, fundamental principles, use in systems and circuits and applications in analogue computing; with electrical and mechanical details and information on power supplies, measurements, tests and fault location. From Muirhead and Co., Beckenham, Kent. Also a leaflet on their range of synchros and servo motors.

Aerial Installation for communications receivers. A booklet "Better Radio Reception," giving advice on aerial erection and interference suppression for land and ship stations, from Eddystone (Stratton and Co.), West Heath, Birmingham 31, price 1s.

Carbon Coated Resistors on ceramic rod with axial wire leads (no caps), giving reductions in length and diameter. Details of these and other carbon-coated and wire-wound precision types made by Resista Fabrik Elektrischer Widerstände of W. Germany, in a catalogue from G. A. Stanley Palmer, Maxwell House, Arundel Street, London, W.C.2.

G.E.C. Valve Manual, Part I, second edition, covering receiving and industrial valves, television and instrument c.r. tubes, semiconductor diodes and transistors, neons, photocells, barretters, corona stabilizers and G-M tubes. Also tables of equivalents, valves in G.E.C. receivers and data on obsolete types. From the General Electric Company, Magnet House, Kingsway, London, W.C.2, price 7s 6d.

A.C. Voltage Stabilizers in rack-mounted form suitable for direct incorporation in equipment. Load ratings range between 1.61 and 12.19 kVA, the accuracy is ±0.5 per cent, while the correction rate is 40 volts per second for one design and 1 volt per second for another. Leaflet from Claude Lyons, Valley Works, 4-10 Ware Road, Hoddesdon, Herts.

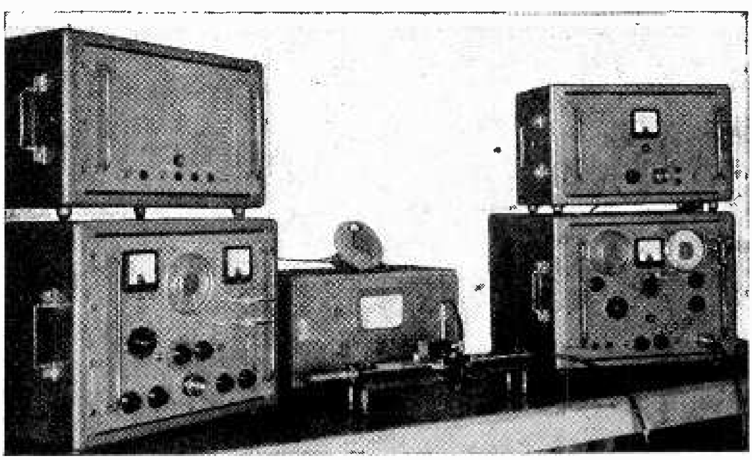
Hi-Fi Furniture.—The provision of various styles of cabinets for sound reproduction equipment to suit customers' existing furnishing schemes is part of the service offered by Largs and described by them in a booklet from their establishment at 76-77, High Holborn, London, W.C.2. Cabinets can be "tailor made" if necessary.

Three-pole Switches, suitable for 3-phase power switching, with a sliding action contact mechanism which ensures simultaneous breaking of all three contacts. These and other Cutler-Hammer types described in a leaflet from NSF, Keighley, Yorks.

Screened Leads, microphone cables and equipment connecting wires; a brochure from The Telegraph Construction and Maintenance Co., Mercury House, Theobald's Road, London, W.C.1.

Batteries and Accumulators, Exide and Drydex, for receivers, hearing aids, torches and other electrical apparatus. A catalogue giving sizes, weights, voltages and prices, including a replacement list of types suitable for battery receivers, from Chloride Batteries, Exide Works, Clifton Junction, Swinton, Manchester.

"Modular" Cushioning, made of rubberized hair, for protecting equipment in transit. The "modules" are small blocks of the material on a ⅛-inch flexible backing which can be either cut to separate the blocks or used as a "hinge" when disposing them around corners, etc. Illustrated brochure, showing arrangements required for various loads, from Hairlok Laboratories, Power Road, Chiswick, London, W.4.



U.H.F. Link Test Equipment

For testing u.h.f. multi-channel links a number of special types of equipment are needed. A small exhibition of such test apparatus made by Marconi Instruments, Ltd. and suitable for frequencies from 1,700 to 2,300 Mc/s was held recently. The u.h.f. receiver, signal and noise generators, associated power pack, wavemeter and precision slotted line shown in the photograph formed part of this exhibition.

More Transformerless Amplifiers

RECENT WORK ON SINGLE INPUT SERIES-CONNECTED OUTPUT STAGES

IT seems to be an example of some natural law of cussedness that review articles are rapidly followed by a spate of further publications on the subject; and the article on "Output Transformerless Amplifiers" (February, 1957, issue, p. 58) has proved no exception. As some of this further work has followed what were only sidelines of the original article, further information is given here, together with notes on other developments.

The Philips single input series-connected output stage (shown in Fig. 1, based on Fig. 3 on the Feb., 1957, article) has been more fully described[1]. The signal input for the upper valve already contains second-harmonic distortion produced by the lower. This will give second harmonic in the upper valve by *amplification*, and this will be out of phase with the second harmonic produced by *distortion* in the upper valve. The signal input for the upper valve is out of phase with that for the lower as it is produced by amplification in the lower valve. Thus the second harmonic distortions generated by the valves themselves tend to cancel in the load, as in a push-pull stage. The second harmonic conveyed to the load by amplification in the upper valve can then only be cancelled as well if the upper valve contributes more out-of-phase second harmonic distortion. One way of achieving this is to decrease the distortion produced by the lower valve by using an un-bypassed cathode bias resistor to give current feedback. However, this increases the output impedance and necessitates a higher input voltage. It is better to shift the working point of the upper valve in the direction of increased distortion by altering the value of the cathode bias resistor, although this gives exact compensation at only one value of the output. In practice it was found that this adjustment of the working point was only critical for low outputs. Using two EL86s and no feedback, 9 watts output at 10% total distortion was obtained. This distortion included 8% third harmonic and 6% second harmonic. Results are also given in ref. 1 for the cases when the current of either or both EL86 valves is 25% less or greater than the rated value. The output impedance of this type of circuit is lower than that for the two valves in parallel because the upper valve operates rather like a cathode follower in which only part of the output is fed back.

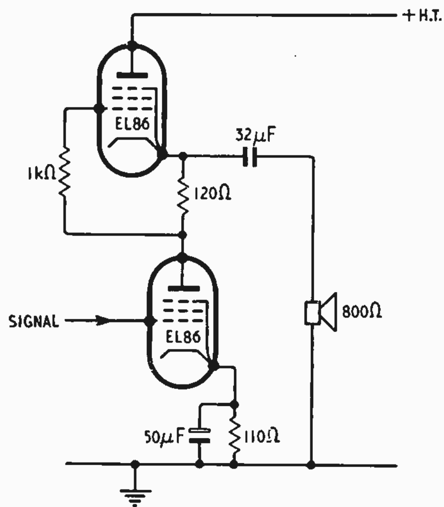


Fig. 1. Philips single input series-connected output stage.

The two versions of this circuit with one of the output pentodes replaced by a triode are also analysed in ref. 1. The maximum output power is obtained when the contribution from the triode is very small or zero. The performance is however then inferior to that of a single class-A operated pentode, both as regards output power and distortion.

Circuits similar to Fig. 1 have also been described in refs. 2 and 3. In ref. 2 it is used as the basis of a high-level, video-frequency modulator. In this application the load is very non-linear as it consists of a capacity in parallel with an effective resistance determined by the grid current in the following stage, i.e., a resistance varying with the output level. In ref. 3 the upper valve is used to provide a high effective resistance to increase the gain of the pentode lower valve.

An analysis of various types of phase inverter connected as in Figs. 7, 8 and 9 of the February, 1957, article with emphasis on obtaining equal drive in the output valves independent of the value of the load has been published by Amemiya[4]. This shows the at least geometrical similarity between Figs. 7 and 9 of the February, 1957, article, where in each case one return from the phase inverter is taken to the anode-cathode join of the output valves. Ref. 4 also shows how in the Coulter circuit (Fig. 8 of the Feb., 1957, article) the drive in the output valves can be made independent of the load value by choosing suitable values for the feedback fraction and the fraction of the input fed to the phase inverter.

Peterson-Sinclair Circuits

The Peterson-Sinclair output stage[5] (shown in Fig. 2, based on Fig. 9 of the Feb., 1957, article) has been analysed by several authors[1, 4, 6, 7, 8]; refs. 4, 6, 7 and 8 emphasizing methods of obtaining equal drive in the output valves independently of the load. Ref. 6 also discusses the optimum valve and operating parameters. Ref. 1 points out that if tetrodes or pentodes are used for the output valves, then the anode current for the lower will exceed that for the upper by the screen grid current, so that the operating points for the two valves will not be identical. Bypassing the lower valve

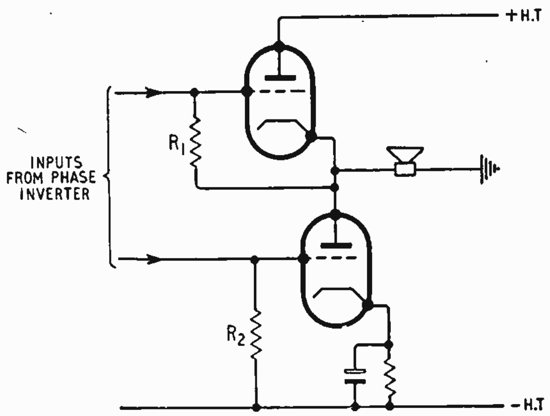


Fig. 2. Peterson-Sinclair output stage.

by a suitable resistor will compensate for this unbalance, though strictly only for one value of the output power.

The effect of the feedback via the anode voltage of the phase inverter in the Peterson-Sinclair output stage is calculated in refs. 1 and 6. According to the former, the reduction in the distortion is only slight and considerably less than the reduction in the output impedance. In one practical case the reduction ratios were 1.07 and 6.6 respectively.

The effect of the stray capacity at the upper phase inverter load R_1 in Fig. 2, is also calculated by Yeh.[6] As pointed out by Peterson and Sinclair[5], because this load is connected in series with the output, this stray capacity is effectively multiplied by one plus the gain in the output stage, much as in the Miller effect. This effect does not occur at the lower phase-inverter load R_2, so that there is some unbalance at high frequencies. In the region where the gain is not affected by phase shift, this can obviously be compensated for by putting an equal effective capacity across the lower phase-inverter load. This was done in practical amplifiers described in Refs. 1 and 8. In Ref. 1, with no feedback, the response was only 3 dB down at 650 kc/s using two EL86s as output valves and half an ECC83 as phase inverter. Figures for the variation of the distortion in this circuit with load value, power output and supply voltage are also given in ref. 1. The distortion appears to fall just before full output. In the amplifier described in ref. 8, using two triode connected 50L6s as output valves and a 6SN7 as cathode-coupled phase inverter, the frequency response was 3 dB down at about 200 kc/s with 20 dB overall feedback. 3 watts with 0.7% intermodulation distortion were obtained in a 600-ohm load.

Another Philips practical circuit similar to Fig. 4 of the Feb., 1957, article, but with a more elaborate phase inverter consisting of two cathode-coupled valves in cascade has been described. [1, 9, 10, 11] The common cathode resistor produces positive feedback in the phase inverter stage. It is shown in refs. 1 and 9 that if this feedback is adjusted so that this stage by itself would be on the verge of instability, then the output stage does not contribute to the total distortion in the amplifier. The whole amplifier can be stabilized with overall negative feedback provided that the output stage and feedback loop do not introduce any undesirable phase-shifts. This proviso can be satisfied much more easily if there is no output transformer. Using two EL86s as output valves to feed an 800-ohm load, 10 watts output with a total harmonic distortion of 0.3% was obtained. The high frequency response was 3 dB down at 250 kc/s, and the output impedance only about 20 ohms.

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2 V. S. Cooper, "Shunt-Regulated Amplifiers," *Wireless Engineer*, Vol. 28, No. 5, May 1951, p. 132.

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4 H. Amemiya, "Analyses of Drivers for Single-Ended Push-Pull Stage," *I.R.E. Trans., Audio*, Vol. AU-3 No. 5, Sept.-Oct. 1955, p. 162.

5 A. Peterson and D. B. Sinclair, "A Single-ended Push-pull Audio Amplifier," *Proc. I.R.E.*, Vol. 40, January 1952, p. 7.

6 C. Yeh, "Analysis of a Single-Ended Push-Pull Audio Amplifier," *Proc. I.R.E.*, Vol. 41, No. 6, June 1953, p. 743.

7 H. Amemiya, "The Extended Cathode-Coupled Phase Inverter and its Application to Single-Ended Push-Pull Amplifiers," *Jnl. A.E.S.*, Vol. 3, No. 2, April 1955, p. 82.

8 H. Amemiya, "An Output Transformerless Amplifier," *Jnl. A.E.S.*, Vol. 4, No. 2, April 1956, p. 72.

9 J. R. de Miranda, "Audio Amplifiers with Single-Ended Push-Pull Output," *Philips Technical Review*, Vol. 19, No. 2, 1957, p. 41.

10 J. R. de Miranda, "Versterkers met Direct Gekoppelde Luidsprekers," *Nederlands Radiogenootschap*, Vol. 22, No. 1, Jan. 1957, p. 15.

11 J. R. de Miranda, "Hi-Fi Philosophy from a European Point of View," *I.R.E. Trans., Audio*, Vol. AU-5, No. 4, July-Aug. 1957, p. 82.

12 J. Futterman, "A Practical Commercial Output-Transformerless Amplifier," *Jnl. A.E.S.*, Vol. 4, No. 4, October 1956, p. 163.

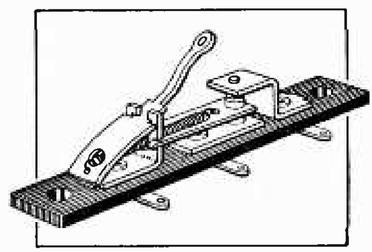
13 L. H. Light, "Feedback Arrangements in Transformerless Push-Pull Output Stages," *Mullard Tech. Comm.* Vol. 3, No. 24, May 1957, p. 102. Refers to transistor output stages.

Skeleton Snap-action Switch

RECENTLY introduced by Arcolectric (Switches), Ltd., Central Avenue, West Molesey, Surrey, is a new sensitive skeleton-type snap-action switch intended primarily for incorporating in small industrial equipment. It is a single-pole change-over type operating on the microgap principle and measures 2⅛ in × ⅜ in over the connecting tags. The height is under ⅝ in.

At rest the armatures and lower fixed contacts are closed and light pressure on the operating lever snaps the spring-loaded armature over to the top fixed contact. Releasing the operating lever allows the armature to return to its rest position. Silver contacts are fitted.

The switch, Model T280, is rated at 3 A, 250V and is for a.c. circuits only; it costs 3s 6d



Arcolectric Model T280 skeleton snap-action switch.

News from the Industry

E.M.I. Records, who provided the tape recording used by the B.B.C. in its recent stereophonic test transmissions, announce that they have been building up a library of stereo tapes during the past few years and, therefore, have the material for processing stereo discs. Before putting them on the market they are developing a suitable pickup. The first E.M.I. stereo discs could be available in about a year.

Elliott Brothers (London), Ltd., who have had for some time a special department for the sale and servicing of American-made Bendix aviation and radio equipment, have discontinued this department. They will now concentrate on the manufacture in this country under licence of the wide range of Bendix-designed equipment.

Semiconductors, Ltd., the recently formed Plessey subsidiary, expect that their transistor factory now being built at Cheney Manor, Swindon, Wiltshire, will be in production by the middle of this year. The air-conditioned factory has no windows, is clad entirely with aluminium panelling, and all interior surfaces are coated with p.v.c.

Marconi Instruments have received an order from the Ministry of Supply for a quantity of f.m./a.m. signal generators for use by the army. The order, valued at nearly £70,000, calls for 117 signal generators Type TF937, which cover the frequency range 85 kc/s to 30 Mc/s, and 94 Type TF995A/3/S covering 1.5-220 Mc/s in five bands.

A. H. Hunt (Capacitors), Ltd., announce that they have discontinued the sale of the CRB3 capacitor analyser and resistance bridge. It will in future be marketed by their subsidiary, F. C. Robinson & Partners, Ltd., of Councillor Lane, Cheadle, Cheshire. The price of the CRB3 has been increased to £27 10s.

E.M.I. Electronics, Ltd., have supplied a substantial part of the television equipment for the studios of the I.T.A. programme contractors T.W.W., Ltd., at Pontcanna, Cardiff. The equipment includes two film-scanning channels, some 30 picture monitors, line selector instruments and two mobile microwave links.

Cossor (Ireland), Ltd., has been formed in the Republic of Ireland to distribute Cossor domestic sound and television equipment. It will also market Cossor instruments and communications and navigation equipment. The address is 51, South William Street, Dublin (Tel.: Dublin 72080).

Texas Instruments, Ltd., who started transistor production at their Bedford factory in September, announce substantial price reductions of silicon transistors. The lowest-priced small-signal type (2S001) is reduced from £4 6s to £3 15s, and the highest-priced high-power type (2S012) from £32 5s to £29.

Solartron Electronic Group had a turnover during the year ended June 30th of over £1M—an increase of £250,000 over the previous year. During the last three years its staff has increased from 240 to 600 and floor space occupied from 30,000 to 70,000 square feet.

Marconi Marine have been installing new transmitters and radar equipment in the liner *Mauretania* while she has been undergoing a major refit at Liverpool. The new radar equipment, the "Radiolocator IV", provides the navigator with three alternative types of display, "north stabilized", "ship's head up", or "track indication" giving the course and speed of responses.

Stability Capacitors, Ltd., of Commerce Estate, Raven Road, London, E.18, have been formed to market the silvered ceramic and silvered mica capacitors manufactured by Stability Radio Components, Ltd., which will continue purely as a manufacturing concern. The directors of both companies are W. Schick and A. Schick.

Quality approval by the Services of the Sentercel silicon power diodes RS20A, RS21A and RS22A is announced by the Rectifier Division of Standard Telephones & Cables.

Amplivox, Ltd., have been awarded a further series of contracts (£10,000 approx.) by the Ministry of Transport and Civil Aviation for the supply of lightweight headsets.

R.E.E. Telecommunications, Ltd., of Somerset, have acquired new premises at 15a, Market Square, Crewkerne, Somerset (Tel.: Crewkerne 662), to which all correspondence regarding their v.h.f. radio-telephone equipment should be addressed.

Perth Radios, Ltd., which was formed in 1953, recently moved from Judd Street, London, W.C.1, to Marten House, East Road, London, N.1. Production of radio-gramophones is now at the rate of 280 per week. The founder and managing director of the company is M. H. Ismail, who came to this country from Pakistan in 1953.

Aerialite, Ltd., have opened a larger Glasgow distribution centre at 311, Bell Street, C.4 (Tel.: Bell 2014/5).

Bradmatic Productions, Ltd., has been formed jointly by Bradmatic, Ltd., the tape-recorder manufacturers of Witton, Birmingham, and Littlewood Bros. (Aerials), Ltd., aerial installers, of Handsworth, Birmingham. The new company, which has its offices at Soho Hill, Birmingham, 19, will undertake large-scale production of a range of equipment including tape-recorder heads and fractional horse-power motors.

EXPORT NEWS

Hanover Fair.—A group of nine companies—English Electric, Gresham Transformers, Painton, British Electric Resistance Co., Pena Industries, Peto Scott, Geo. Bray, Cosmocord and Ardente—have formed what is to be known as Electronics Components Centre (Great Britain), Ltd., to sponsor a joint exhibit at the Hanover Fair (April 27th-May 6th). R. W. Hardisty is secretary of the organization, which has offices at 8 West Street, Epsom, Surrey. The company, which has been formed because of the stipulation that a 10-year contract to exhibit at the fair has now to be signed, will organize a British Electronics Centre at Hanover and possibly at other fairs in the European Economic Community.

A Decca Navigator Chain is to be established in the New York area. The contract has been placed with Bendix-Pacific, the United States licensees of the Decca Navigator Co., by the Air Modernization Board. The chain, which is planned to be brought into service by April 1st, will be the fifth in the Western Hemisphere—four were opened in Canada last year.

Italy.—A section of the 36th International Fair being held at Padua from May 31st to June 15th is to be devoted to sound and television equipment. Further information can be obtained from the sole agents in the U.K.—Auger & Turner Group, Ltd., 40 Gerrard Street, London, W.1 (Tel.: Gerrard 4951).

Nuclear Instrumentation and control circuitry for Denmark's new research reactor to be constructed at Risö, is to be provided by Ekco Electronics.

Electronic eqnipment for the defence forces of the German Federal Republic to the value of £500,000 has been ordered from Decca Radar, Ltd.

Airborne Radar.—The Vickers "Viscount" airliners operated by the Iraqi Airways are being fitted with Ekco Search Radar.

Test Equipment.—J. H. Buying, who has been with Marconi Instruments seven years and was recently appointed sales engineer for Africa and the Middle East, is on a four months' tour of Africa. He will be visiting the Sudan, Ethiopia, Aden, Kenya, Tanganyika, Central African Federation, Portuguese East Africa, Union of South Africa, Belgian Congo, French Equatorial Africa, Nigeria, Ghana and Sierra Leone.

An I.S.B. transmitter is being supplied by Marconi's for installation at the station of the South African Posts and Telegraphs Department at Klipheuvel. The 10-kW h.f. transmitter, which replaces equipment supplied by Marconi's in 1930, will be used for telegraph and telephone traffic with the U.K.

British Columbia.—An International Trade Fair is being sponsored by the government of British Columbia to mark the centenary of the Province. It will be held in Vancouver (May 1st-10th) and one of the sections will include sound and television equipment, precision instruments and electrical equipment.

Sound Reproducing Equipment.—Birmingham Sound Reproducers announce that orders from the U.S.A. for delivery in the first quarter of this year exceed $2.5 million.

A Belgian office has been opened by Evershed & Vignoles, Ltd., at 142, rue Gallait, Brussels, where the company's range of instruments and control equipment will be available for Belgium, Belgian Congo and Luxemburg.

MARCH MEETINGS

LONDON

4th. I.E.E.—Discussion on "Some impressions of technical and industrial training in the United States" opened by Dr. K. R. Sturley at 6.0 at Savoy Place, W.C.2.

10th. I.E.E. Graduate and Student Section.—"The International Geophysical Year" by Sir Archibald Day at 6.30 at the Institution of Civil Engineers, Great George Street, S.W.1.

12th. Radar Association.—"The Jodrell bank radio-telescope in action" by Prof. A. C. B. Lovell at 7.30 at the Anatomy Theatre, Gower Street, W.C.1.

13th. Television Society.—"Transistors in television receivers" by B. Overton (Mullard Research Labs.) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

18th. Institute of Physics.—"Microwave ferrites" by L. A. Thomas (G.E.C. Research Labs.) at 5.30 at 47 Belgrave Square, S.W.1.

18th. Brit. I.R.E.—Discussion on the Technical Committee's report "Recommended method of expressing electronic measuring instrument characteristics: (1) a.m. or f.m. signal generators" at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

19th. I.E.E.—"Efficiency and reciprocity in pulse-amplitude modulation" (1) Principles by K. W. Cattermole; (2) Testing and applications by J. C. Price; and "Transistor pulse generators for time-division multiplex" by K. W. Cattermole at 5.30 at Savoy Place, W.C.2.

21st. R.S.G.B.—"The junction-type transistor and its application to short-wave radio" by E. Wolfindale and L. E. Jansson (Mullard) at 6.30 at the I.E.E., Savoy Place, W.C.2.

25th. I.E.E.—"The atomic clock" by Dr. L. Essen at 5.30 at Savoy Place, W.C.2.

26th. Brit. I.R.E.—"Electronics in medicine" by R. F. Farr at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

27th-28th. I.E.E.—Convention on radio aids to aeronautical and marine navigation at Savoy Place, W.C.2.

28th. Royal Institution.—"Hearing in man and animals" by Dr. R. J. Pumphrey (Derby Professor of Zoology, University of Liverpool) at 9.0 at 21 Albemarle Street, W.1.

31st. I.E.E.—"Future radio-communication methods for civil aircraft" bv W. E. Brunt at 5.30 at Savoy Place, W.C.2.

ARBORFIELD

11th. I.E.E. Graduate and Student Section.—"The fidelity limits of monaural sound reproduction" by J. B. Helder at 7.0 in the Assembly Hall, 3 (Tels.) Training Bn., R.E.M.E.

BEDFORD

11th. I.E.E.—"The transatlantic telephone cable" by R. J. Halsey at 6.30 at the Swan Hotel.

BIRKENHEAD

21st. Brit. I.R.E.—"Radio exploration of the galaxy" by Dr. J. E. Baldwin at 7.0 at the Technical College.

BIRMINGHAM

24th. I.E.E.—"Colour television" by Dr. D. A. Maurice at 6.0 at the James Watt Memorial Institute, Great Charles Street.

BRISTOL

11th. Television Society.—Mullard film lecture on "Ultrasonics" at 7.30 at the Grand Hotel.

CAMBRIDGE

25th. I.E.E.—"Domestic high-fidelity reproduction" by J. Moir at 8.0 at the University Arms Hotel.

CARDIFF

14th. Institute of Physics.—"The cybernetic approach to mentality and society" by Dr. W. Grey Walter (Burden Neurological Inst.) at 5.15 in the Department of Physics, University College of South Wales and Monmouthshire.

CHATHAM

3rd. I.E.E.—"Electronics and automation—some industrial applications" by Dr. H. A. Thomas at 7.0 at the Medway College of Technology, Maidstone Road.

CHESTER

17th. I.E.E.—"Recent uses of ultrasonics in investigating the characteristics of materials" by Dr. J. Lamb at 6.30 at the Town Hall.

DUBLIN

20th. I.E.E.—"The design and acoustical treatment of broadcasting stations with particular reference to the new Radio Eireann Cork studio" by E. J. Slowey and P. A. Kneafsey at 6.0 in the Physical Laboratory, Trinity College.

EDINBURGH

18th. I.E.E.—"The B.B.C. sound broadcasting service on very-high frequencies" by E. W. Hayes and H. Page at 7.0 at the Carlton Hotel, North Bridge.

GLASGOW

13th. Brit.I.R.E.—"Automatic reading of typed or printed characters" by C. E. G. Bailey at 7.0 at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent.

HATFIELD

27th. I.E.E.—"Electrical synthesis of music" by A. Douglas at 7.0 at the Technical College.

IPSWICH

3rd. I.E.E.—"The B.B.C. sound broadcasting service on very-high frequencies" by E. W. Hayes and H. Page at 6.0 at the Crown and Anchor Hotel.

LIVERPOOL

31st. I.E.E.—"Colour television" by L. C. Jesty and Dr. E. L. C. White at 6.30 at the Royal Institution, Colquitt Street.

MALVERN

10th. I.E.E.—"Tracking the earth satellites with the aid of radio interferometry" by D. B. Yale at 7.30 at the Winter Gardens.

28th. Brit.I.R.E.—"Transistors in reception" by L. E. Jansson at 7.0 at the Winter Gardens.

MANCHESTER

19th. I.E.E.—"Domestic high-fidelity reproduction" by J. Moir at 6.45 at the College of Science and Technology.

26th. Brit.I.R.E.—"Electronic handling technique" by R. N. Settle at 6.30 at the Reynolds Hall, College of Technology, Sackville Street.

NEWCASTLE

3rd. I.E.E.—"Radio in air-sea rescue" by G. W. Hosie, D. Kerr and W. Kiryluk at 6.15 at King's College.

12th. Brit.I.R.E.—"Industrial television" by S. G. Gobbi at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

17th. I.E.E.—"Some transistor input stages for high-gain d.c. amplifiers" and "A transistor high-gain chopper-type d.c. amplifier" by Dr. G. B. B. Chaplin and A. R. Owens at 6.15 at King's College.

PAIGNTON

27th. B.S.R.A.—"A modern high-quality reproducing system" by H. L. York (Cape Electrophonics) at 7.30 at Standard Telephones & Cables, Brixham Road.

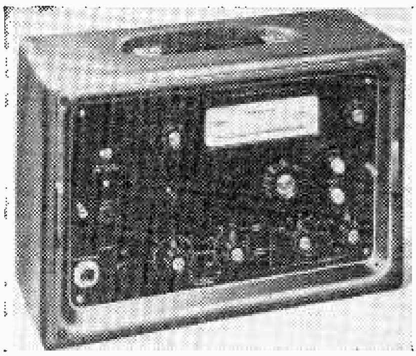
WOLVERHAMPTON

12th. Brit.I.R.E.—"Analogue computers" by K. C. Garner at 7.15 at the Wolverhampton and Staffordshire Technical College, Wulfruna Street.

MANUFACTURERS' PRODUCTS

Audio Oscillator

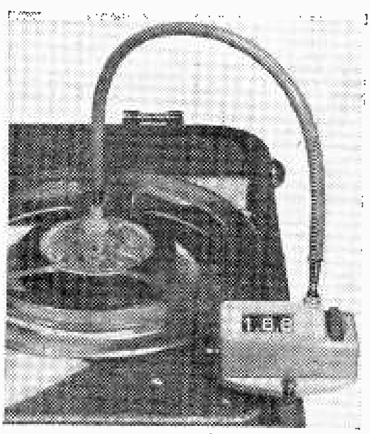
A CONTINUOUSLY variable control allows interpolation between adjacent fixed frequencies in the Wayne-Kerr S121 oscillator. Ten equally spaced fixed frequencies may be selected in each of four decade ranges to cover in all from 10c/s to 120kc/s. Alternative outputs are available, one at a level variable in 1 dB steps from +10 dB to −70 dB referred to 1 mW at an impedance of 600 ohms, and the other at a continously variable level in five decades up to 30 volts at an impedance of 3,300 ohms. Frequencies may be set to an accuracy of 1% or ±0.5c/s whichever is the greater, and the output level is constant to within 0.2 dB over the whole range. The total harmonic distortion is less than 0.2% from 300c/s to 20kc/s, and does not rise outside this range to more than 2.5% at 10c/s. The instrument costs £130 and the address of the manufacturer is Wayne Kerr Laboratories, Ltd., Roebuck Road, Chessington, Surrey.



Left: Wayne Kerr audio oscillator offering continuous variation between fixed frequencies.

Tape Revolution Counter

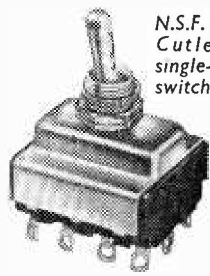
THE photograph shows how the new Philips EL3979/17 three-digit revolution counter may be readily fitted to their AG8109 tape recorder. Attachment to their models AG8105 and AG8107 is also possible via the carrying handle. In each case the plastic cap at the end of the drive cable is simply pushed over the top of the spool spindle. A reset wheel is fitted to the counter. The price of the counter is £3 7s 6d.



Philips tape spool revolution counter.

Appliance Switches

TO their range of Cutler-Hammer appliance switches N.S.F. Ltd., 31-32, Alfred Place, London, W.C.1, have added several new one-hole fixing 3- and 4-pole models rated at 10A on 250V a.c. supplies or 20A in d.c. circuits not exceeding 24 volts.



N.S.F. new 4-pole Cutler-Hammer, single-hole fixing switch.

Measuring approximately 1$\frac{7}{8}$in × 1$\frac{1}{2}$in × 1$\frac{3}{8}$in the 3-pole type have spring-loaded silver-alloy contacts with sliding action arranged to break simultaneously all 3 circuits. The switches are lever operated and available with either a 2- or a 3-way movement. The 2-way provide "on/off" switching and the 3-way has a centre "off" position with an "on" position either side of it.

Apart from their usefulness in various electrical appliances both models have many applications in electronics, process control and automatic production systems.

Design Pointers

THE current issue of *Design*, published by the Council of Industrial Design, includes an appreciation of details in the design of the Vidor "Vagabond" receiver. Considering the general status of the portable set the authors point out that because of the increasing interest in television, sound radio receivers have become ancillary equipment and the portable is no longer part of picnic equipment but "is about to develop as a general purpose instrument which is neither luggage nor furniture."

Basic functional requirements for the design of dials are considered by Brian Shackel, of E.M.I. Electronics, in another article.

RANDOM RADIATIONS

By "DIALLIST"

Is "Piping" the Answer?

A LETTER from a Portslade-by-Sea, Sussex, reader received early in January left me for some time completely flabbergasted. "I was glad," he wrote, "to see in the last lines of your notes this month confirmation of my views expressed in a letter to *W.W.* in last July's issue." The rest of his letter made it clear that he was referring to "piped" television. I knew I'd referred to this some time ago, but certainly not in the January, 1958, issue. A post or two later came the explanation. Both the '57 and '58 issues for January happened to be lying on his desk, each with a blue cover. He'd picked up the last year's one and had read the note I'd written about the difficulties of obtaining acceptable Band III reception in not a few parts of the Sheffield area. Well, over a year has passed since then and I can see no reason to change the opinion I then had that in some parts of the country, at any rate, the only complete answer seemed to be a service of "clean" TV signals sent over wires from a master receiving station operating in a place clear of all kinds of interference. Few people, I suppose, are more fortunately situated for television reception than I. My aerial is 60 feet above road-level and my home is on an open green, round which there is very little motor car traffic. There are no unsuppressed electrically driven machines and no flashing signs anywhere near. Aeroplanes rarely fly overhead. We are not in the service area of a Band III transmitter; but when our local station is brought into service I don't thing there'll be any bother.

The Not-so-lucky

Many others are not so well off. Unless we take real steps to protect their interests by outlawing preventable interference a large proportion of the nearly eight million television receiver owners in this country will have willy-nilly to put up with directly received pictures that are constantly upset or even blotted out by its effects. I do feel that in many built-up areas, particularly those containing tall metal-framed buildings and factories using a multiplicity of electrically powered machines, piping is likely to be the simplest and most effective solution of the problem. Nor can I see that there's any real reason for set manufacturers to be opposed to it. Why, for instance, shouldn't they make models specially designed to deal with piped signals where such are available? Surely, if a good picture, steady and immune from interference, could be guaranteed, the result would be larger sales and a greater number of satisfied customers.

Not Always So Simple

EVER since Jeans astonished the world by producing a scientific best-seller in his "Universe Around Us" there has been a steady flow of popular books on astronomy, physics, nuclear energy and other subjects. They are eagerly read by people athirst for knowledge, who either buy them, or borrow them from their county libraries. Many of them are quite admirable for their clear explanations of difficult things—in so far as they can be explained with a minimum of mathematics. Some, though, are apt to befog their readers quite needlessly by the use of physicists' jargon which is completely unintelligible to the man in the street. Why, for example, if the authors of such books mention Max Planck's equation, do they have to state it as $E=h\nu$? Many—perhaps most—of their readers are unfamiliar with the Greek alphabet and to such ν stands for vee and nothing else. I know that the physicists will steadfastly refuse to abandon ν in favour of f. By all means let them keep it, if they really feel that they need two letter symbols for the same thing, despite the fact that so many letters (μ, for instance) are hopelessly overworked in different—and not always so different—branches of science. But it's out of place in popular books. Confusion is worse confounded when they write power as joules/sec. Many people have never heard of such things, but they have at any rate some idea of what a watt is, for they know that a 75-watt lamp gives more light and consumes more current than a 40-watt. When American books of this kind make their way over here another snag crops up. American writers are fond of the word billion, which to them doesn't mean 10^{12}, as it does to our folk, but 10^9. I could go on and on with my protests, but readers will themselves think of many other instances they've come across of how simple-minded readers seeking for knowledge can be unintentionally blinded wi' science.

Optical "Noise" Filter

AS ONE who has to wear a very powerful lens in front of an eye damaged some years ago, I can possibly add my personal experiences to the opinions in letters in the January issue from T. G. Clark and E. R. Slaughter on pin-hole vision. In my work-room I have an old bracket clock with a nine-inch dial and stout black hands. Without the lens I find that I can not read the time at a distance of much over 15 inches. But looking through a pin-hole I find that I can do so quite easily (both hands and figures being seen sharply) at a good 10-12 feet. Years ago, I remember an eminent oculist telling me that the effect was exactly the same as that seen in the pin-hole camera: the small aperture cuts out the "noise" produced by light rays coming in at wide angles from the line of vision, brings the wanted rays to a focus and projects them on to the screen, photographic plate, or retina, as the case may be. Anyone, I think, who has to wear glasses will find that (though it's much more limited in angle) his pin-hole vision without glasses is as sharp and clear as his normal sight through spectacle lenses.

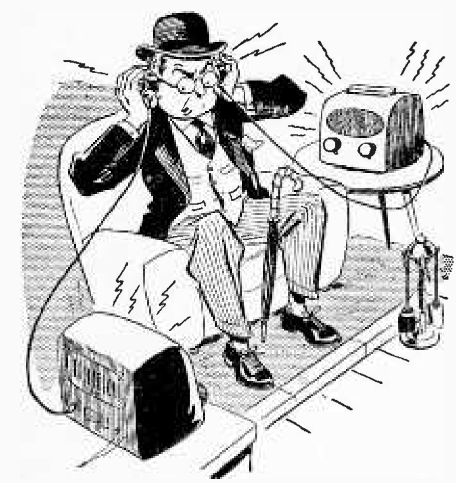
Why Not "Hi-Fi" TV?

THERE'S no question that the development of high-fidelity audio receivers and reproducers has been and continues to be an enormous success commercially. That makes me wonder why no manufacturer, so far as I know (if there be one, he has my humblest apologies), has yet turned his attention to the production of television sets which are of the genuine "Hi-Fi" order. It's been said that no one outside research establishments has ever seen the high quality which our 405-line transmissions are capable of showing on the TV screen. There's a whole lot in that, you know. Here are some points where a "Hi-Fi" set, costing naturally a good bit more than the domestic receiver of to-day, could show its worth. The interlace would be perfect and the linearity both horizontal and vertical far better than it is in most sets. Sharp definition without a trace of ringing would be essential and there could be a considerable improvement in the tone gradations from black through dark grey and pale grey to white. A designer who hadn't to consider every penny would have full scope for improving automatic picture control and for obtaining a close approach to perfection in sync methods. People don't seem to mind much what they pay for "Hi-Fi" sound equipment and I honestly believe that the same would soon be true of television receivers that could be relied upon to bring out on their screens everything conveyed by the vision signals—and nothing else.

Direct from Heat

IT'S MORE than annoying to come across in one's morning paper an account written by a layman of some new development in wireless or electronics and to be unable to find either in it or elsewhere the technical particulars one wants. That happened to me last month, when I read a brief account of a thermionic convertor, developed by Dr. Volney C. Wilson, of the American G.E.C. Now I've got hold of details and pictures of the apparatus. The main idea is to convert heat direct into electricity without the use of any intermediate stages or moving parts. This can, of course, be done by the thermocouple; but the output is minute. Dr. Wilson's apparatus is in essence a diode and anyone who possesses a diode and a sensitive galvanometer can satisfy himself that the thing is possible. Connect the anode *via* the galvanometer to the cathode, switch on the l.t. and you'll find a deflection. What happens is that most of the electrons emitted by the cathode form the space charge surrounding it. But some of them are energetic enough to make their way to the anode, where they produce an electron surplus. Connect anode to cathode outside the bulb and these electrons cause a flow of current. Pictures show Dr. Wilson surrounded by giant diodes. Their cathodes are run at white heat and very promising results have been recorded. The efficiency is already as high as 8 per cent and it is hoped that as the process is developed efficiencies of 30-35 per cent may be reached.

UNBIASED By FREE GRID



"I did as I was bidden" (or did he ?—Ed.)

"*Ni-Fi*" *Stereophony*

WHEN the B.B.C. carried out its experimental stereophonic transmissions in January, I did as I was bidden, placing one receiver to the left of me and t'other to the right. The results were certainly more than merely "hi-fi"; they were very nigh unto "ful-fi" and, therefore, worthy to be called "ni-fi."

But both Mrs. Free Grid and I felt that we were missing something which we should have got had we been present in the flesh at the original performance of the items being broadcast. It is not without significance, I think, that the B.B.C. makes use of the word "stereophonic" to designate these transmissions, for my much-tattered lexicon tells me that the Greek word "stereo" is a verb meaning "I rob, or deprive of something." Stereo, is, therefore, *le mot juste*, for I do feel that I am being robbed or deprived of something, namely, just that little extra realism which my presence in the studio would give me.

Having thus set the philologists by the ears and made them grab their pens to tell the Editor and me quite truly that the word "stereo" isn't derived from its Greek namesake at all, I will now proceed to do the same with the technologists by stating that true realism can only be obtained if the separate-channel link be maintained to the bitter end by using moving-coil headphones, with one earpiece connected to each of the two channels.

To those of you who use your heads for purposes other than that of keeping a hairdresser and his family in comfort, it should be quite clear that if you sit in the studio, listening to, say, a violinist, each ear receives the sound from its own particular "viewpoint." Above all, one ear can't possibly hear, even faintly, the sound which the other ear does.

But this is not so if one is sitting between two separate-channel loudspeakers. The left ear can and does hear, albeit faintly, the emanations from the right-hand loudspeaker, and vice versa. The disturbing effect is small but it does exist and only separate-earpiece headphones can make reception as truly binaural as it is in the studio.

In the world of steroscopy we are careful to use separate "eyephones." Although the cinemas have made gallant attempts to get rid of these by various subterfuges, they have never achieved quite the same degree of realism. In other words, their results are "ni-fi" like the B.B.C.'s recent stereophonic experiments.

By the way, can anybody tell me where I can get a pair of really "hi-fi fones," even better than the moving-coil types at present available. Preferably they should have two annular diaphragms, the outer one having an m.c. movement and the inner a piezo-crystal one. The centre core should, of course, be an electrostatic tweeter.

77 cm/sec and 78 r.p.m.

IT is difficult to find suitable words in which to express my thanks to Mr. H. Davies, of the B.B.C. Engineering Division, for the wealth of information he gave me in last month's issue about tape recorder speeds. The correcting of my ignorance was just the thing I was fishing for in my note in the January issue. I have always found that the best way to obtain information about any matter is to make a dogmatically tomfool statement about it or to ask a naïve question.

A remarkable instance of this occurred once when Mrs. Free Grid and I stood before a statue of Beethoven in Bonn. I had told her all about the terrible handicap of Beethoven's deafness, and her innocent question "Why on earth didn't the poor man invest in a good hearing aid?" instantly brought forth a wealth of information from one or two English-speaking teutonic bystanders eager to correct her terrible anachronism.

There is one point on which even Mr. Davies confesses himself ignorant and that is why the precise value of 77 cm/sec was chosen for the original magnetic recorder. My guess is that the reason was the same as that which led to the choice of 78 r.p.m. for the disc recorder. In both cases the figure could have been raised to a round 80 without causing technical trouble. The reason was probably that in each case the figure chosen represented the average of many experimental records made at slightly different speeds. However, I think I can hear, on my psychic receiver, the sound of several of you savants reaching indignantly for your pens.

My thanks are due also to the Editor for the support he gave me and I accept his rebuke for trying to immortalize one who was a commercial impresario of magnetic recording rather than a technological tycoon. On first thoughts I was afraid that the Editor had put me in a dilemma as a predecessor in the Editorial chair had added a comment to an earlier note I wrote about Herr Stille over a quarter of a century ago.

This note said that Stille was the *inventor* of magnetic recording. However, the Latin verb *invenire*, which gives us the word inventor, does not mean to "originate" but to "come upon, or find." This is exactly what Stille did. He came upon magnetic recording and proceeded to put it on the map. I think the same is true of Marconi with regard to radio.

Thus Stille was indeed the inventor of magnetic recording but only in the literal sense of the word. Therefore everybody is correct and I do not find myself in the unpleasant position of divided loyalties.

Technology Without Tears

I WAS very interested in "Cathode Ray's" article on atoms (February issue). He is a past master at "technology without tears" and I'm sorry he isn't going to deal with nuclear energy.

In view of what he wrote recently about the passing of the ether theory into the limbo of the lost, I wish he could give us an article in Lewis Carroll style called "Alice in Waveland."

"Go and have a bathe, child," said the Red Queen, "but be careful that the waves don't knock you over."

"But there is no sea to have a bathe in," protested Alice.

"I never said there was," replied the Queen, "I meant you to bathe in the sea waves and warned you to be careful that they didn't knock you over."

"But how can there be waves without any sea for them to travel in," asked Alice in a bewildered tone.

"You're just being stupid," said the Queen and turning to her executioner snapped "Off with her head."