5 — To be Completed in about 20 Fortnightly Parts — 1s/3d

HARMSWORTH'S WIRELESS ENCYCLOPEDIA

For Amateur & Experimenter

CAL—COI

CONSULTATIVE EDITOR

SIR OLIVER LODGE, F.R.S.

THIS PART CONTAINS

86 Practical and Theoretical Articles

192 New "Action" Photos & Diagrams

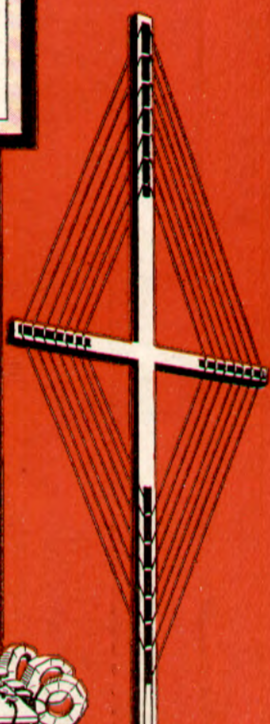
Many 'How-to-Make' Articles

Cardboard Tubes for Formers—Cascade Amplification—Celluloid Working—Charging Board Circuits of All Kinds—Cockaday Receiver Construction—Coils, Making and Winding

SPECIAL THREE-FOLDER PLATE OF

HOME-MADE COIL WINDERS

J. LAURENCE PRITCHARD, F.R.Ae.S., Technical Editor, with expert editorial and contributing staff



The Only A B C Guide to a Fascinating Science-Hobby

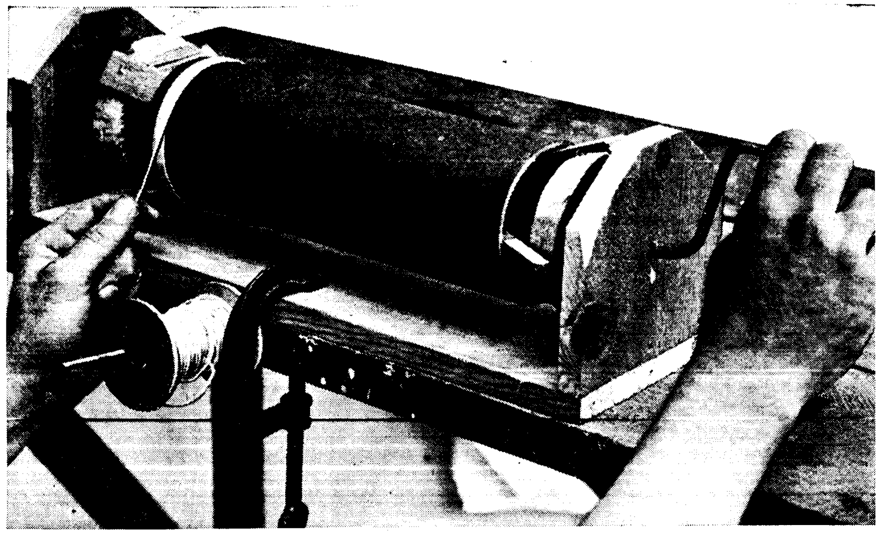


Fig. 13. Simply made and efficient winder for the home constructor. Note method of supporting spool of wire

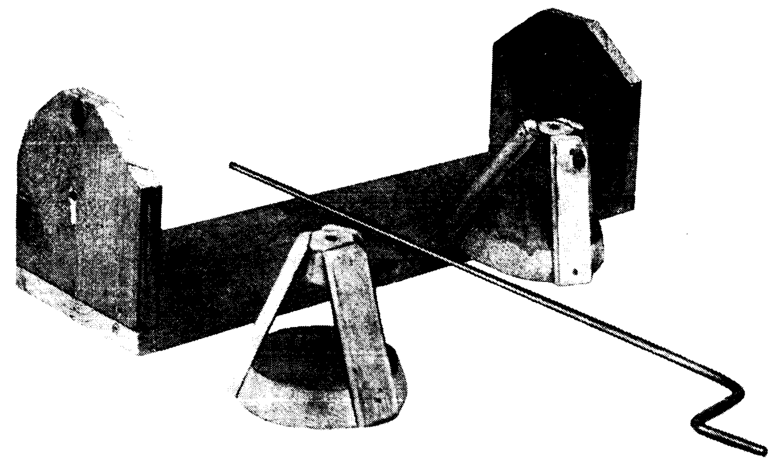


Fig. 14. Component parts of the winder. The tapered supports allow various-sized coils to be held firmly

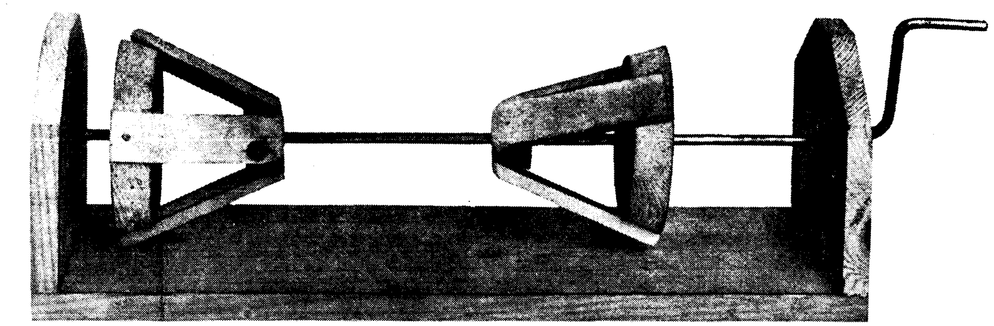


Fig. 15. The coil winder assembled ready for use. The supports slide on the axle to permit different lengths of coil to be wound

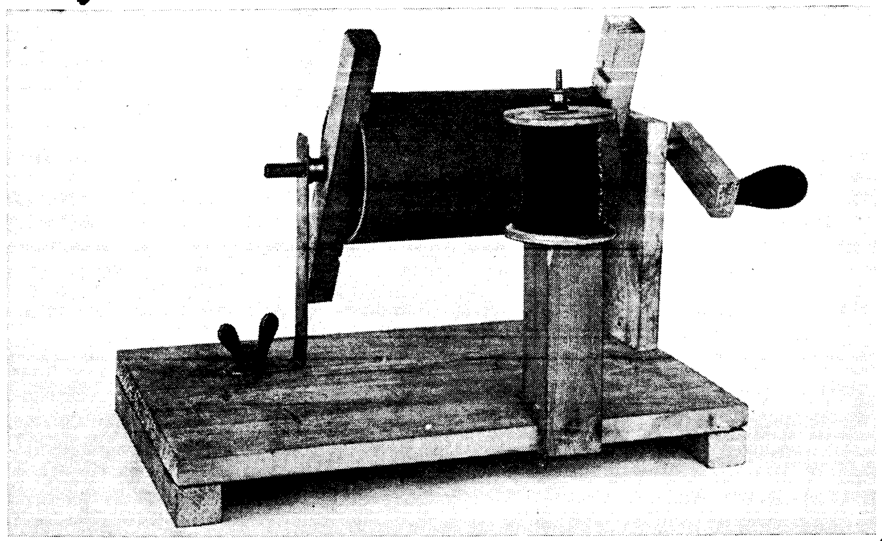


Fig. 16. Improved type of adjustable winder. Grooves cut in the supporting pieces take various sizes of formers

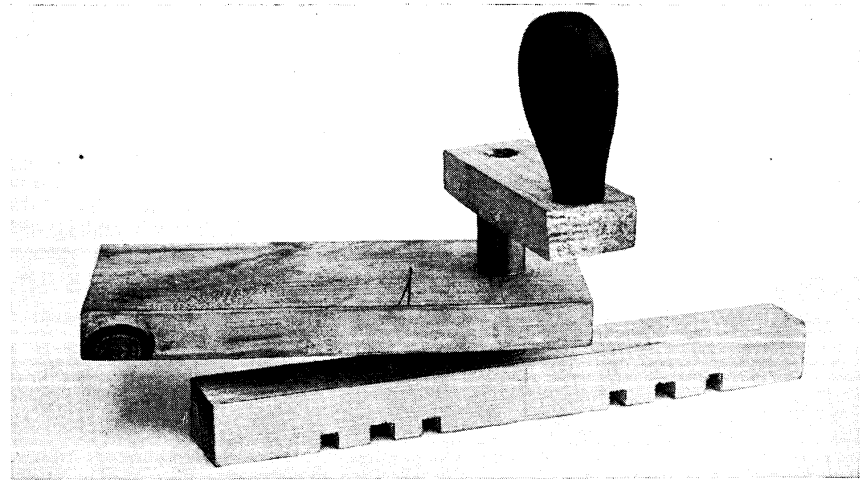


Fig. 17. Details of the head stock of the coil winder seen in Fig. 16, showing simplicity of construction

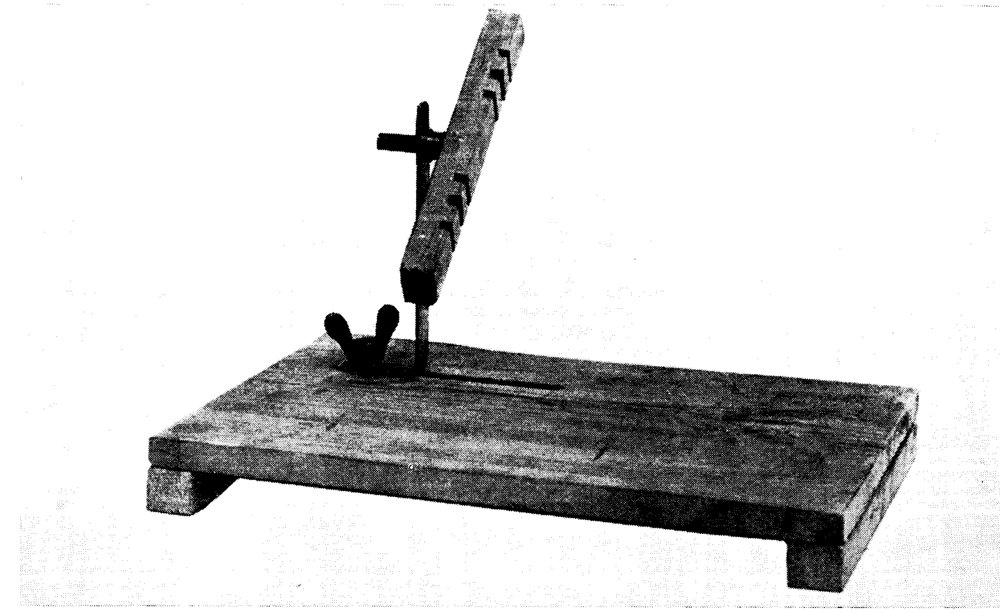


Fig. 18. Details of base and tail stock. The support is made of strip brass, adjustable in a slot and held by bolt and flynut

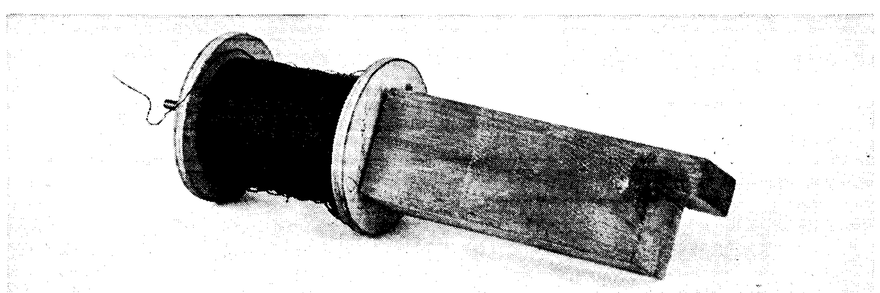


Fig. 19. Spool and supporting arm. It is fixed vertically, and is free to revolve on a steel peg

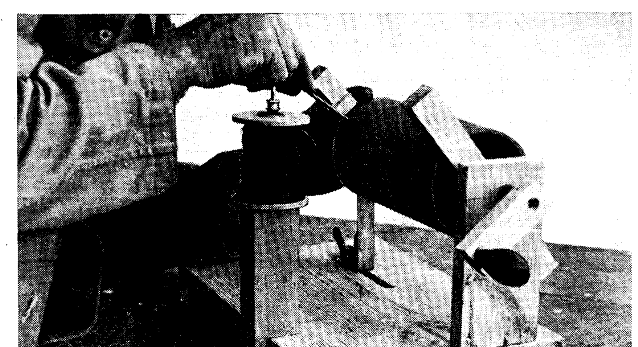


Fig. 20 Using the winder for a plain inductance coil, first stage

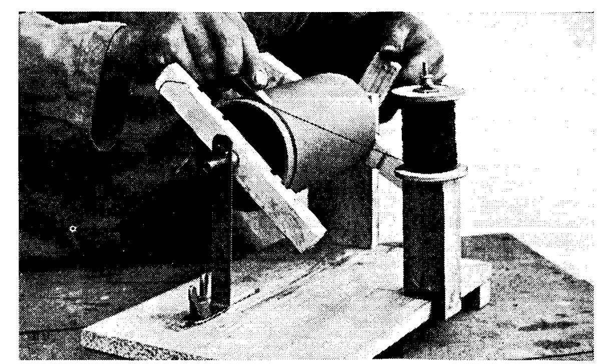


Fig. 21. Later stage in winding. Note method of guiding wire

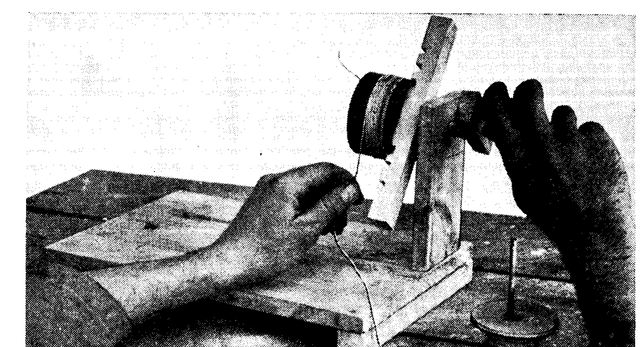


Fig. 22. Winding a short former for a variometer. Head stock only is used

COIL WINDING: TWO EASILY CONSTRUCTED AND EFFICIENT MACHINES WHICH ENABLE THE AMATEUR TO WIND COILS OF ALL KINDS FOR HIMSELF

To face page 458]

From photographs specially prepared for HARMSWORTH'S WIRELESS ENCYCLOPEDIA

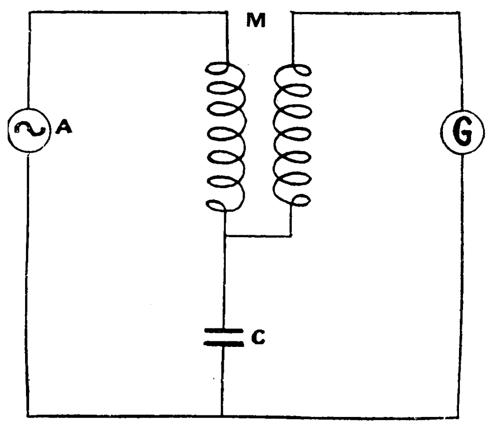
5 I G J. E. Sheldrick, B.Sc.(Eng.), G.I.Mech.E., The Brambles, Third Av., Denville, Havant
5 I K B. L. Stephenson, 12, Sheringham Rd., Withington, Manchester
5 I L Dr. A. Dinsley, Carlton, Ince Av., Great Crosby, Liverpool
5 I O Wireless Equipment, Ltd.(Test Station), R. H. Brown, 10, Coverdale Rd., Shepherd's Bush, W.12
5 I P R. H. Knox, 25, Bridge St., Berwick-on-Tweed
5 I S J. S. Foord, 93, Herne Hill, S.E.24
5 J B D. Prive-Jones, 45, Toothill Rd., Loughborough, Leicestershire
5 J C I. J. Morris, Seames Bay, Anglesey
5 J D F. Bulmer, 4, Carlton Terrace, Scarborough
5 J G R. F. Longley, 81, Langdale Rd., Thornton Heath, Surrey
5 J J L. D. G. Morrison, Cults House, Cults, Aberdeenshire
5 J K North of Scotland Wireless Co., 13, Bridge St., Aberdeen
5 J M W. Woods, 8, Brighton St., Barrow-in-Furness
5 J N S. Wilkinson, Messrs. Bew & Co., Burslem, Staffs
5 J R W. C. P. Hepworth, Moorings, Dovercourt
5 J S H. B. Burdekin, 9, Marine Av., Westcliff-on-Sea
5 J X M. G. Scroggie, B.Sc., 37, Cluny Gardens, Edinburgh
5 J Z H. J. Cheney, 262, Thimble Mill Lane, Nechells, Birmingham
5 K A G. C. Beddington, Stagsden, West Cliff Rd., Bournemouth
5 K B F. Westrup Coomber, Electrical Engineer, 58, The Tything, Worcester
5 K L G. M. Wood, 60, Pikes Lane, Glossop, Manchester
5 K N J. Earnshaw, 95, Mayfield Rd., Sanderstead
5 K O I. W. Higgs and J. S. Hobbs, 45, Howard Rd., Westbury Park, Bristol
5 K P A. T. Wallace, Brettenham, Hedge Lane, Palmer's Green, N.13
5 K W R. Hodges, Holly Mount, Westdale Lane, Maperley, Notts
5 K Y E. E. G. Allsopp, Ingle Nook, Wigginton Rd., Tamworth
5 L A L. H. Soundy, 60, Bellevue Rd., Ealing
5 L D Denman St., London
5 L F Secretan & Mallet, Ltd., 149, Lowther Parade, Barnes, S.W.13
5 L G J. G. Johnston, 43, Oak Rd., Hale, Cheshire
5 L J E. Jackson, 37, Manley Rd., Whalley Range
5 L O J. W. Clough, 142, Revidge Rd., Blackburn
5 L P L. W. Pullman, 213, Golders Green Road, N.W.11
5 L S W. H. Bloxham, 99, Old Dover Road, Blackheath, S.E.
5 L V N. Wilson, Claremont, Tenbury Road, King's Heath, Birmingham
5 L Z A. G. S. Gwinn, 61, Carnarvon Rd., Stratford, E.15
5 M A R. Munday, 17, Malden Rd., New Malden
5 M C W. Woodhams, 24, Marlborough Place, Brighton
5 M D R. W. Hardisty, 5, Ethelbert Rd., Canterbury
5 M J C. F. Howes, Enfield
5 M L O. R. Healey, 11, Glebe Rd., Wallasey
5 M O W. G. Dixon, Dipwood, Rowlands Gill, Newcastle-on-Tyne
5 M P Colin Bain, 51, Grainger St., Newcastle-on-Tyne
5 M Q City & Guilds Wireless Soc., Kensington
5 M R N. P. Stoate, 15, Winterstoke Gardens, Mill Hill, N.W.7
5 M S Manchester Wireless Soc., Houldsworth Hall, Deansgate
5 M T " " "
5 M U C. W. Titherington, Dorchester
5 M Y W. G. Wyatt-Ingram, 41, Lambert Rd., S.W.2
5 N D J. H. Taylor & Co., Electrical Engineers, Macaulay St., Huddersfield
5 N F R. W. Galpin, Bank House, Herne Bay
5 N H A. C. Hulme, 39, Poplar Av., Edgbaston
5 N N J. H. R. Ridley, Studley, 106, Woodside Green, S. Norwood, S.E.25
5 N P Eric P. Burgess, 2, Queen's Rd., Manningham, Bradford
5 N Q A. C. Mercer, 82, Lumb Lane, Bradford
5 N T C. H. Friskarp, 23, Tennyson St., Lincoln
5 N W E. J. Allen, 8, Westfield Place, Dundee
5 O C Col. E. C. Jennings, C.B.E., J.P., 11, Burlington Place, Eastbourne
5 O D R. Eates, Holmeside, St. Catherine's, Lincoln
5 O J J. Warburton, 47, Clayton Rd., Bradford
5 O L J. F. Cullen, 68, Queen's Drive, West Derby, Liverpool
5 O T F. J. Wood, Belmont, Upper Colwyn Bay
5 O W H. Green, Norman House, Swinton, nr. Manchester
5 O X C. H. F. Hubbard, 196, Putney Bridge Road, S.W.15
5 O Y Belvedere & District Radio & Scientific Soc., Erith Technical Institute
5 P H C. Metcalfe, Flacton Works, Halifax
5 P J A. Shaw, 8, Hall Rd., Trawden, nr. Colne, Lancs
5 P R C. Ratcliffe, 68A, Dewsbury Rd., Leeds
5 P S J. E. Catt, Melrose, Alexandra Rd., Farnborough, Hants
5 P T Peterborough
5 P U T. Allison, 33, Wilton Grove, Merton Park, S.W.
5 P V R. G. Templar, 52, Alderville Rd., Hurlingham
5 Q B A. G. Bainton, 8, Palace Rd., Streatham Hill, S.W.2
5 Q D G. H. Wray, 19B, Church Gate, Loughborough, Leicestershire
5 Q I D. G. Bird, 8, Osborne Ter., South Shields
5 Q M V. R. Mills, 122, Hughenden Rd., Hastings
5 Q V F. L. Stollery, Fairmead, Vista Rd., Clacton-on-Sea
5 Q X Messrs. Holt & Dedman, 6, Raby Road, New Malden
5 R B A. R. V. Garnett, Southwell Park Rd., Camberley
5 R C W. Brierley, 59, Gayner Park, Filton, Bristol
5 R F L. F. Hunter, 18, Tannsfield Rd., Sydenham, S.E.26
5 R L J. A. Sang, 22, Stranmillis Gardens, Belfast
5 R M Peto Scott Co., 64, High Holborn, E.C.
5 R P Capt. H. I. Hughes (Hughes & Watts, Ltd.), Engineers, Oxton, Birkenhead
5 R Q G. W. Tomkin, 164, Cold Harbour Rd., Westbury Park, Bristol
5 R W J. W. Elliott, Havering, nr. Romford
5 R Z A. G. Wood, 93, Upper Tulse Hill, S.W.2
5 S A Mercian Radio Co., Radio Works, Hinckley
5 S D J. Turner, Barwythe, nr. Dunstable
5 S F J. K. Wilkie, Avondale, Knowsley Rd., Cressington Park, Liverpool
5 S I C. L. Naylor, 43, Hill Crescent, Longdon Rd., Shrewsbury
5 S P E. Warner, Dilnott, Horsham
5 S Q A. P. McGrory, 58, Kirk St., Campbeltown
5 S T R. R. Morrison, Spring Grove, Hilbarchan, Renfrewshire
5 S U Capt. Ian Fraser, St. John's Lodge, Inner Circle, Regent's Park, N.W.1
5 S W C. Bedford, Turton Hall, Gildersome, nr. Leeds
5 S Z J. W. Riddiough, Lawnside, Sandals Rd., Baildon
5 T A V. I. N. Williams, Merok, Lees Rd., Bramhall, Cheshire
5 T F P. A. Gooding, 16, Cambridge Rd., Hammersmith, W.6
5 T G F. R. W. Strafford, 3, Lee Rd., Dovercourt
5 T H A. G. Suthers, Tilmore, Petersfield, Hants
5 T I J. Bonnett, 159A, Turner's Hill, Cheshunt
5 T L E. D'Eresby Moss, 4, St. George's Terrace, Regent's Park, N.W.1
5 T Q H. Rayner, 32, Grange Rd., Cleckheaton, Yorks
5 T R A. J. Cooper, 8, Cowley Rd., Ilford
5 T S W. Dean, Bankleigh, Ramsgreave, nr. Blackburn
5 T U J. Leigh-Rodger, Woodside, Western Terrace, Falmouth
5 T V Lieut. W. H. Lloyd, 27, Copthall Gardens, Twickenham
5 T W Capt. R. Stanton Baugh, Longfield, Wake Green Rd., Moseley, Birmingham
5 T X " " "
5 U A A. Barber, 15, Harrington Terrace Lidget Green, Bradford
5 U C J. Gardener, Lewis Rd., Sutton
5 U L J. L. Coverney, 12, Wallwood Rd., Leytonstone, E.11
5 U M H. Alchin, 78, Chester Rd., Forest Gate, E.7
5 U O R. Simmonds, 61, Brightfield Rd., Lee, S.E.12
5 U Q J. C. L. Edwards, Trevor Hall, Ruabon
5 U S J. Croysdale, 5, Elm Grove, Burley-in-Wharfedale, Leeds
5 U V L. A. Jeffreys, 90, Harringay Rd., Green Lanes, N.15
5 U X H. Stephenson, The Bottoms, Gildersome, Leeds
5 U Y D. B. Fry, The Laurels, Mayfield, Sussex
5 V D F. J. Wakefield, 31, Station Rd., Church End, Finchley
5 V K B. Caldwell, Caverswall, Lower Walton, nr. Warrington
5 V P G. F. Kitchen, 10, Beech Rd., Epsom
5 V R Hendon, Middlesex
5 V T G. C. Webb, 10, Osborne Rd., Stroud Green, N.4
5 V U S. W. Butters, 51, Clarendon Rd., W
5 V W W. V. Harrington, 51, First Av., Hoe St., Walthamstow, E.17
5 V X J. H. Ives, 49, Acme Rd., Watford
5 W D K. Ullyett, 25, Harrington Rd., Leytonstone, E 11
5 W F D. G. Bower, Van Buren, Upper Richmond Rd., Putney, S.W.15
5 W M J. B. Renshaw, Wireless House, Old Chapel St., Blackburn
5 W R C. E. Morriss, Southernbay, Heron Hill, Belvedere, Kent
5 W U R. B. Cross, 9, Ormsby Av., Gorton Mount Estate, Gorton, Manchester
5 W Z E. W. Hettich, 1, King St., Jersey

5 X C I. H. Lott, Bushey
5 X M F. Eustace, 92, Briardale Rd., Morsley Hill, Liverpool
5 X R F. A. Tuck, 87, Mayo Road, N.W.10
5 X S F. B. Thomas, 7, Mornington Villas, Wanstead, E.11
5 X T P. B. Thompson, 1, Chase Side Place, Enfield Town
5 X U T. N. Lord, 6, Trafalgar Ter., West Park St., Dewsbury
5 X Y J. C. Harrison, 10, Lake Rd., Fairhaven, Lytham, Lancs
5 X Z A. F. C. Boyes and L. M. T. Bell, 48, Lavender Gardens, S.W.11
5 Y D E. R. Bridgewater, 23, Deacon Rd., Widnes
5 Y I A. L. Goodliffe, 17, Malvern Rd., Nottingham
5 Y M Capt. E. H. Robinson, Langmead, Pirbright
5 Y Q J. Gallocher, 4, Havelock Ter., Paisley
5 Y S C. H. Dyke, Trevena, Streetsbrooke Rd., Shirley, Birmingham
5 Z H T. Allison, Cromwell Engineering Co., 127, Fulham Rd., S.W.
5 Z O W. F. Mills, 11, Stoney Hey Rd., New Brighton
5 Z R F. H. Austin, 52, Church St., St. Peters, Broadstairs
5 Z T E. Edwards, 18, Ripon St., Moss Side, Manchester
5 Z V W. Herring, 221, Newark Rd., Lincoln
5 Z X T. Rawson, Maudsley House, Thornton, Preston
5 Z Y L. Headlan, Stakeby Rd., Whitby, Yorks
5 Z Z H. C. Witby, The Ness, Winsford
6 A A Durham and Northumberland Collieries Fire and Rescue Brigade, Rescue Station, 854, Scotswood Road, Newcastle-on-Tyne. (F. P. Mills)
6 A B " " "
6 A F R. H. Rice, 70, Seaside, Eastbourne
6 A G W. H. Fortington, 237, Dudley Rd., Rotton Park, Birmingham
6 A J G. Ensoll, 25, Victoria Rd., Dukinfield
6 A L J. P. Morter, 49, Westow Hill, Upper Norwood, S.E.
6 A O A. Ruddlesden, 24, Wakefield Rd., Dewsbury
6 A W E. J. Jarvis, Electricity Works, Ilkley, Yorks
6 B B J. Bolt, Crouchley, Lymm, Cheshire
6 B C W. Douglas Clague, White House, High Heworth, Gateshead
6 B J C. L. Solomon, 10, Cavendish Rd., Brondesbury, N.W. 6
6 B N G. Minvalla, 25, Weighton Rd., Anerley, S.E.20
6 B Q J. L. Cannon, 14, Woodcrott Av., Broomhill, Glasgow, W
6 B R G. H. Ramsden, Overdale, Ilkley, Yorks
6 B V V. F. M. Oliver, Whitmore Lodge, Sunninghill, Berks
6 B W J. C. Mason, 8, Westmoreland Rd., New Brighton
6 C F W. C. Lingard, Bridgeholme Green, Chapel-en-le-Frith, Derbyshire
6 C G A. W. Eagle, 42, Park Lane, Tottenham, N.17
6 C I C. E. Tilley, 10, Guthlaxton St., Highfields, Leicester
6 C W D. Burne-Jones, Gwalier, Rustic Av., Streatham, S.W.16
6 D C G. Young, 15, Anslow Street, Harpurhey, Manchester
6 D J A. C. Copsey, 27, Sutherland Rd., Tottenham, N.17
6 D M Capt. C. Knight-Cootes, 16, Vine St., Evesham
6 D P N. Crowther, 219, Roundhay Rd., Leeds
6 D U E. J. Newton, 1, Jerningham Rd., New Cross, S.E.14
6 D W D. Johnson, 131, Clapton Common, E.5
6 D Z Capt. L. A. K. Halcomb, South Dene, 106, Millhouses Lane, Sheffield
6 F H G. W. Livesley, 19, Shropshire St., Market Drayton
6 F K Worcester Cadet Signal Co. Junior Technical School, Sansome Walk, Worcester
6 F L E. Kirkby, 36, Bank Rose St., Halifax
6 F Q A. B. Richardson 9, Quarry Rd., Hastings
6 F V W. H. Taylor, 37, Bridge St., Warrington
6 F Z P. H. C. Hallam
6 G C H. H. Burbury, Crigglestone, nr. Wakefield, Yorks
6 G M E. A. Wilson, Roxburgh, 42, Heber Rd., Cricklewood, N.W.2
6 G O L. A. Sayce, 5, Toward Ter., Sunderland
6 G W P. Brian, 70, Wakeley Lane, Hall Green, Birmingham
6 G Z R. E. Neale, Farnborough Rd., Farnborough, Hants
6 H D National Wireless and Electric Co., Church Rd., Acton, W. 3
6 H F Yorkshire
6 H K J. W. F. Cardell, Tretherras, Newquay
6 H R W. D. Keiller, 51, Highworth Rd., New Southgate, N.11
6 H S H. Saville, 1, Delmare Av., Stretford, nr. Manchester
6 H V W. J. Butler, 15, Algernon Rd., Edgbaston
6 H X C. H. Noke, Misidia, Ripley
6 H Y F. Dyer, 59, Antill Rd., Tottenham, N.15
6 I C A. Jowett, 310, Hopwood Lane, West End, Halifax
6 I D F. Wheatley, Jnr., 24, Radnor Rd., Handsworth
6 I G E. Brady, 6, Coltesgate Hill, Ripon, Yorks
6 I L J. H. Roscoe, 183, Chester St., Birkenhead
6 I M Highgate
6 I X W. G. Fudger, Brora, Priorswood Rd., nr. Godalming
6 J B Wimbledon Radio Soc., Red Cross Hall, Church Rd., Wimbledon, S.W.19
6 J S P. R. Solder, 76, Albert Rd., Alexandra Park, N.W 22
6 J L ——, Edgeleigh, Warwick Av., Coventry
6 J V Capt. H. J. B. Hampson, 477, Earlham Rise, Norwich
6 J X R. J. W. Lankester, Wanderings Farm, Kingston Rd., Kingston-on-Thames
6 J Z V. A. G. Brown, Fawley Lodge, Edey Av., Reading
6 K C Radio Speciality Co., 4, Heaton St., King St., Blackburn
6 K K J. Cookson, 66, Albert Rd., Blackpool
6 K U H. G. Clacy, 114, Bradshaw Rd., Watford
6 L B L. J. Fuller, Glenburn, Seagry Rd., Wanstead
6 L J S. K. Lewer, N.W.6
6 L W R. C. Davies, Sunnyside, 22, Graingers Lane, Cradley Heath, Stafford
6 M G B. W. D. Lacey, 33, Woodbridge Rd., Moseley, Birmingham
6 M Q C. B. Patching, 84, Allcroft Rd., Kentish Town, N.W.5
6 M U E. J. White, Lansdowne Villa, Rochdale Rd., Blackley, Manchester
6 N F A. D. Gay, 49, Thornlaw Rd., West Norwood, S.E.27
6 N G J. Cropper, 10, Manor St., Hooley Hill, nr. Manchester
6 N H J. W. Davies, Doddington, Caterham Valley
6 N S J. Frater, Felling-on-Tyne
6 O B F. W. Woodward, 5, Portland Gardens, Harringay, N.4
6 O N W. H. Felton, 47, Sompting Rd., Broadwater, Worthing
6 O X B. Quentin, Lislet Lodge, St. Sampsons, Guernsey
6 O Z H. Thompson, 7, Rye St., Chorlton-on-Medlock, Manchester
6 P D A. J. Dixon, 74, Hartford Rd., Enfield Wash
6 P G C. H. Targett, 21, High St., Dartford
6 P J F. Ison's Stores, 47, Orchard Rd., Walthamstow, E.17
6 P K Universal Radio Co., 129, New Bridge St., Newcastle-on-Tyne
6 P S W. F. Hurndall, 211, Grove Lane, Camberwell, S.E.
6 P T L. Lott, Gnats Muir, Berrow Rd., Burnham-on-Sea
6 Q C Grammar School, Loughborough
6 Q Y J. A. Godfrey, 160, Bethune Rd., Stamford Hill, N.16
6 R O Morgan & Taylor's Radio Electric, Ltd., 122, Wellington St., Cardiff
6 R W J. W. Elliot, 16, Liberty Cottages, Havering, Romford
6 S Q Chas. Rodgers, 3, Alders Av., Chinley, via Stockport
6 T D K. L. Palmer, Vyrnwy House, Llansaentffraid, Montgomeryshire
6 T N E. H. Wright, 13, Boyces St., Brighton
6 V L R. W. Leader, 93, Pinner Rd., Harrow
6 V T S. O. Pearson, 35, Bishopsthorpe Rd., Sydenham, S.E.22
6 U C A. C. Chatwin, 162, Hagley Rd., Edgbaston, Birmingham
6 U F C. P. Finn, Ardnalia, Wath-on-Dearne, Rotherham
6 U M D. E. Pettigrew, Woodhouse Lane, Church School, Leeds
6 Z Y Leslie Gordon, 133, Old St., Ashton-under-Lyne, Lancs
8 A A A. Riss, 38 bis, Boulevard Sante-Beuve, Boulogne-sur-Mer
8 A B Leon Deloy, 55, Boulevard Mont-Boron, Nice, Alpes Maritimes
8 A C Achille Fabre, Rue du Roc, Albi, Tarn, France
8 A D J. Roussel, 12, Rue Hoche, Juvisy-sur-Orge, Seine-et-Oise
8 A E Dr. P. Corret, Paris
8 A E La T. S. F. Moderne, 11, Av. de Saxe, Paris
8 A F Radio Club de France, 95, Rue de Monceau, Paris
8 A G Colmant, 16, Av. de Robinson, Chatsnay par Sceaux
8 A H Marcel Coze, 7, Rue Lalo, Paris
8 A N C. Biemans, 167, Boulevard du Montparnasse, Paris
8 A O M. Lardry, Radio Club de l'Ouest, Boulevard Negrier, Le Mans, Sarthe
8 A P J. J. Peugot, Sous Roche, par Audincourt, Doubs, France
8 A Q M. Sassi, Arpaion, Seine-et-Oise
8 A R M. Le Saulnier, Boisguillaume par Rouen, Seine Inferieure
8 A S M. Paul Coisy, 76 bis, Av. du Chemin de Fer, Rueil, Seine-et-Oise
8 A U M. Barrelier, Le Mans, Sarthe
8 A V M. Yvan Voos (Radio Club de Reims), 20, Rue Worle, Reims
8 A Y G. Thuillier, 11, Rue d'Ornan, a Alger, France

CALORIE. This is the C.G.S. unit of heat. It is the amount of heat required to raise one gramme of water one degree centigrade. This is sometimes known as the petit calorie. The amount of heat required to raise one kilogramme of water one degree centigrade is a great calorie. The latter is a more convenient unit, and equals 3·968 B.T.U. or British Thermal Units, or 3087·3 foot-pounds.

CAMPBELL'S BRIDGE. Resistance and induction bridge circuits due to A. Campbell for the measurement of capacity and inductance. There are several forms of the bridge, some of them modifications of other well-known bridges.

Fig. 1 shows a form of Campbell's bridge for the measurement of capacity in terms of mutual inductance. M is an



MEASUREMENT OF CAPACITY

Fig. 1. Capacity may be measured by this form of Campbell's bridge. The method adopted is an adjustable mutual inductance

adjustable mutual inductance, C the condenser whose capacity is to be measured, A some source of alternating current, G a galvanometer. By suitably adjusting M the current in the galvanometer may be made zero.

Then $C = 1/w^2M$

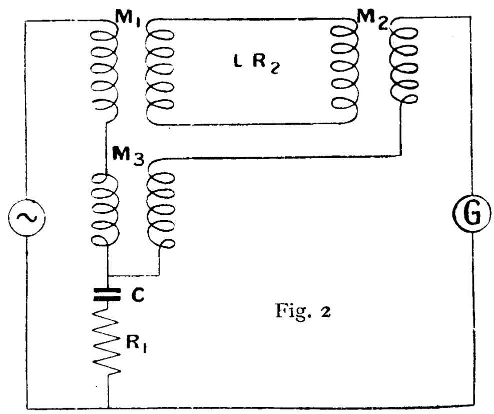
where $w = 2\pi n$, n being the frequency of the alternating source.

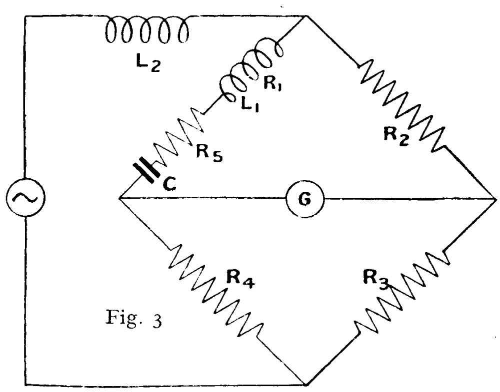
A condenser which shows absorption does not when discharged return the whole quantity of electricity which was put into it when charging. This is known as the power loss, and in that case the circuit of Fig. 2 is adopted. The power loss in C is represented by the resistance R_1. M_1, M_2 are mutual inductances, the secondary coils of which form a closed loop of resistance R_2 and self-inductance L. M_3 is an adjustable mutual inductance connected to the primaries of M_1 and M_2, and these coils are placed away from M_3, so that there is no direct mutual inductance between the primary and galvanometer circuits other than M_3.

By adjusting M_1, M_2, M_3 the current in the galvanometer may be made zero, and we have

$$1/Cw^2 = M_3 + LR_1/R_2$$
$$R_1R_2 = (M_1M_2 - R_1L^2/R_2)w^2$$

From these equations R_1 and C may be calculated. Another arrangement is shown in Fig. 3. The condenser C, with





CAMPBELL'S BRIDGES

Fig. 2. Power loss in a condenser is determined and calculations made by a Campbell's bridge in the above circuit. Fig. 3. Another method of calculating power loss in a condenser is given by this form of Campbell's bridge

the resistance R_5, representing the power loss, is in the arm of the bridge containing L_1R_1, the secondary coil of a variable mutual inductance L_2. R_2, R_3, R_4 are resistances, R_2 being variable.

A balance is obtained without the condenser C, giving values L_0 and R_0 of L_2

and R_2. A second balance is obtained with the condenser in position and a balance obtained with values L^1 and R^1.

Then

$$(L_1 - 1/w^2C)/L^1 = (R_3 + R_4)/R_3$$

$$L/L_0 = (R_3 + R_4)/R_3$$

$$\therefore \quad C = \{R_3/(R_3 + R_4)\}\{1/w^2(L^1 - L_0)\}$$

and similarly

$$R_5 = R_4(R_0 - R^1)/R_3$$

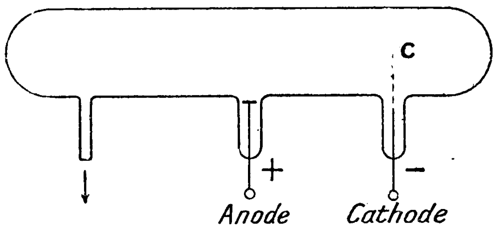
giving the capacity and power factor of the condenser. *See* Anderson Bridge ; Foster Bridge ; Wheatstone Bridge.

CANAL RAYS. When working with highly-exhausted vacuum tubes it was discovered by Goldstein that if a perforated cathode were employed instead of a solid one, luminous streams emerged through the holes in the cathode in a direction opposite to the cathode rays themselves. These rays have been called canalstrahlen or "canal rays."

They produce phosphorescence, and can be deflected by electric or magnetic fields ; but the deflection is considerably less than in the case of true cathode rays, and it requires extremely strong fields to produce any visible effect. The fact that they are deflected, too, in a direction opposite to that of the cathode rays shows that they are positively charged particles. The velocity of these particles has been determined, also the ratio of the charge carried to the mass (e/m). It is found that they travel with a smaller velocity than the cathode rays, also that the ratio c/m is not constant, but varies with different materials.

The maximum ratio found was about 10^4, which is about the same as for the hydrogen ion in electrolysis. This indicates that the mass of these positive ions is at least of the same order as the mass of the hydrogen atom. The positive ion appears, therefore, to be atomic in size, and is at least 1,700 times the mass of the negative ion produced in a gas at low pressure.

These rays may be observed by using a vacuum tube of the form shown in the diagram, about 25 cm. long and 2·5 cm. diameter. The cathode, C, consists of a flat aluminium disk. The disk, C, is perforated by a number of holes, about 1 or 1·5 mm. in diameter. The tube is exhausted to a degree when cathode rays begin to be produced, and as the vacuum is gradually increased, luminous streams



OBSERVATION OF CANAL RAYS

Vacuum tubes as represented by this diagram are used for the observation of canal rays

will be seen emerging from the holes on the side of the cathode farthest from the anode. Phosphorescence will be produced on the glass wall of the tube.

CAPACITANCE. Name suggested by Heaviside for a measured capacity in analogy with inductance, resistance, etc.

CAPACITY : THEORY AND CALCULATION

Measurements of Importance for Aerials and Other Apparatus

Here are explained, with all necessary formulae, how the capacities of apparatus used in wireless work are calculated. Another viewpoint of capacity by Sir Oliver Lodge appears under the heading Electrostatic Capacity. See also under the separate headings dealing with individual pieces of apparatus, e.g. Aerial; Coil; Condenser, etc.

In electricity the capacity of a conductor is defined and measured by the quantity of electricity required to raise the conductor to unit potential when all neighbouring conductors are at zero potential.

Suppose A and B are two conductors distant from any other conductors, and let A be kept at zero potential while B is charged to some potential V. Then if Q be that charge necessary to raise B to the potential V, the following equation holds :

$$Q = C V,$$

where C is the capacity of the conductor B.

If A had been kept at any other potential except zero potential, say a potential V_1, then

$$Q = C (V - V_1).$$

C is usually expressed in microfarads, V in volts, and Q in coulombs. The first equation, as it stands, gives C in farads, so that, to give C in microfarads, the relation between the three quantities is

$$Q = CV/10^6$$

Capacity may be measured in electrostatic units. Here one microfarad equals 9×10^5 electrostatic units. Also, since the dimensions of capacity in electrostatic units are a length times a constant—the dielectric constant—capacities, especially small capacities, are sometimes measured in centimetres.

The calculation of the capacities of conductors of any shape is difficult in most cases, and in many impossible, and such capacities are measured. Certain shapes, however, lend themselves to calculation.

In wireless work the calculation or measurement of capacity is of paramount importance. The capacities of many pieces of wireless apparatus are not only considered here, but are further dealt with under their respective headings.

Single Horizontal Wire. If the radius of the wire be r, its length l, and the height of the wire above the earth h, the capacity is

$$l/2 \log_e (2h/r) \text{ in electrostatic units}$$

$$= l/\{41 \cdot 447 \times 10^5 \log_{10} (2h/r)\} \text{ microfarads}$$

if the earth below is a good conductor and l is large compared with h.

Parallel Horizontal Wires. The case of multiple-wire flat-topped aerials has been considered by Professor Howe, who derived a general formula for any number of parallel wires each of length l, and at distances d apart, and radii r. The capacity in electrostatic units for two wires is

$$l/\{2 \log_e (l/d) + \log_e (d/r)\}$$

For three wires the formula becomes

$$3l/2\{3 \log_e (l/d) + \log_e (d/r) - 0 \cdot 46\}$$

For four wires

$$2l/\{4 \log_e (l/d) + \log_e (d/r) - 1 \cdot 24\}$$

For six wires

$$3l/\{6 \log_e (l/d) + \log_e (d/r) - 3 \cdot 48\}$$

Single Vertical Wire. The capacity of a single vertical wire is, in electrostatic units

$$l/2 \log_e (l/r)$$

$$= l/\{41 \cdot 447 \log_{10} (l/r)\} \text{ microfarads.}$$

This formula is obtained on the assumption that the wire is not near the earth or any other conductors. In actual practice the wire is near the earth, and this alters the capacity. If, for example, the wire is charged positively, there is a negative charge on the surface of the earth round the wire. This opposite charge is known as the electrical image of the wire, and the potential of the wire depends upon its own charge and the effect of this electrical image charge. The potential of the wire is, in fact, decreased and its capacity increased. A more accurate formula, making allowance for this proximity to the earth, is

$$l/10^5\{41 \cdot 447 \log_{10} (l/r) - 15 \cdot 48\}$$

microfarads.

The above results were read by Professor Howe before the British Association in 1914 and 1915, who pointed out in connexion with them that if a single straight, vertical or horizontal wire be charged to a potential above or below that of the earth, the electric charge is not uniformly distributed over the surface of the wire, but is denser at the ends than near the middle. It is also assumed that the earth is a perfect conductor for the calculation of the formula for the capacity of a single horizontal wire. Since the earth never is a perfect conductor the capacity is not so great as given by the formula.

From the formulae, however, an approximation may be made to the capacities of an aerial. The capacity of a multiple-wire aerial, it should be pointed out, is less than the sum of the capacities of each wire taken separately. Fleming has found that four equal parallel wires, for example, placed at a distance of about one-fiftieth of their length apart, have only twice the capacity of one wire, and twenty-five wires have only about five times the capacity of one wire. In such cases the calculation of the capacity becomes uncertain, and it is best to measure the capacity.

But for approximation purposes the formula may be used, with the reservations stated. Most aerials consist of one or more horizontal wires, and a nearly vertical lead-in wire, the T or inverted L aerial. The horizontal wires have potentials due to their own charge and images and the charge on the vertical wires, and similarly for the vertical wires, and these potentials must be taken into account when calculating the capacities.

W. L. Austin gives the capacity of the horizontal wires of a flat-topped aerial as

$$C = \frac{(4\sqrt{A} + \cdot 885A/h)(1 + \cdot 015l/w)}{10^{-5}}$$

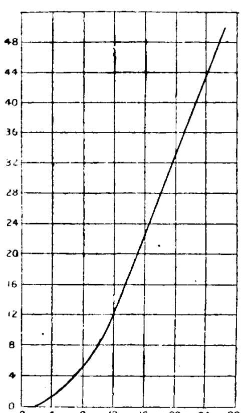
where A= area of the flat top in square metres, h the height of the aerial from the ground in metres, l the length of the aerial in metres, and w its width.

The difficulty of calculating theoretically the capacity of any aerial and its lead-in is not so much that due to considerations of the length of the wires concerned, their diameters, and so on, but to their actual positions with regard to surrounding objects. Trees, houses, masts, etc., all have an effect on the capacity, and this effect cannot be calculated theoretically, though approximations may be made. Professor Howe has, in a paper read before the British Association, 1916, shown one method of taking into account the effect of a cylindrical mast on the capacity of a single vertical aerial, and of a lead-in running parallel to a building.

The following approximate formula, due to Howe, enables the capacity of a multiple-wire aerial to be calculated for all practical purposes, 10 per cent being added to allow for earth and most effects with ordinary L and T aerials:

$$C = \frac{16{\cdot}94n}{n \log_e (l/d) - 0{\cdot}31 + \log_e (d/r) - B}$$

mfd. per foot where n is the number of wires, d their distance apart, r the radius of each wire and B a constant depending on the number of wires. The constant is given by the curve shown in Fig. 1.



AERIAL CAPACITY

This curve gives the constant B for the capacity of a multiple-wire aerial according to Prof. Howe's approximate formula

The capacity of an aerial may be found experimentally by means of the Fleming-Clinton commutator. Briefly the commutator consists of three metal barrels mounted on the same shaft and insulated from one another. A metal brush rubs on each barrel, and the two outer barrels have each four projecting lugs which interleave with the centre barrel, which has eight projections. The centre barrel allows the contact brush to run smoothly and make alternate contact with the outside barrels.

The aerial is connected to the middle barrel. One terminal of a battery and of a movable coil galvanometer are connected to the outside barrels, and their other terminals are earthed. When the commutator is set in motion the aerial is alternately charged by the battery and discharged through the galvanometer.

If V = voltage of battery,
C = capacity of aerial,
A = current in micro - amperes through the galvanometer,
n = number of charges per second,

$$C = A/n\,V.$$

If the operation of charge and discharge is repeated 100 times a second or more, there is a steady deflection of the galvanometer, and by suitably calibrating the latter the capacity may be obtained.

Capacities of Spheres. If r_1, r_2 be the radii of two concentric spheres their capacity is $r_1r_2/9 \times 10^5(r_2-r_1)$ mfd., r_2 being the radius of the outer sphere. The capacity of one sphere is obtained by making r_2 infinite, and the formula becomes $r/9 \times 10^5$ mfd.

Capacities of Cylinders. If r_1, r_2 are the inner radius of the outer cylinder and the outer radius of the inner cylinder, and l the length, the capacity is

$$\frac{l}{4{\cdot}6052 \times 9 \times 10^5 \times \log_{10} (r_2/r_1)} \text{ mfd.}$$

when air is the dielectric.

For any other dielectric if K is the dielectric constant the capacity per unit length is

$$\frac{K}{2 \times 4{\cdot}6052 \times 9 \times 10^5 \times \log_{10} (r_2/r_1)} \text{ mfd.}$$

Capacities of Condensers. The capacity of two flat parallel plates, each of area A, separated by a dielectric whose constant is K and thickness d, is

$$AK/9 \times 10^5 \times 4\pi d \text{ mfd.,}$$

or

$$AK/11309760d \text{ mfd.}$$

For air, K = 1.

If there are $n+1$ plates, each of area A, each separated by a dielectric of thickness d and constant K, the capacity is

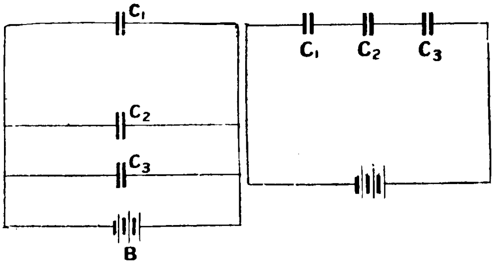
$$nAK/11309760d.$$

The capacity of the ordinary variable condenser is

$$\frac{Kn\,(r_1^2-r_0^2)\theta}{1380d}$$

where r_1 is the radius of the outside edge of the smaller of the sets of plates and r_0 the radius of the inside edge of the fixed plates, n the number of spaces between the plates, and θ the angle in degrees through which the plates have been tuned from zero capacity.

The capacity of a number of condensers arranged in parallel is the sum of their separate capacities. When the condensers are arranged in series, the total capacity is the reciprocal of the sum of the reciprocals of the separate capacities. Thus, if C is the total capacity of condensers whose separate capacities



CAPACITIES OF CONDENSERS

Fig. 2 (left). Capacity of condensers in parallel equals the sum of their separate capacities. Fig. 3 (right). Condensers in series give a total capacity whose reciprocal is the sum of their reciprocals

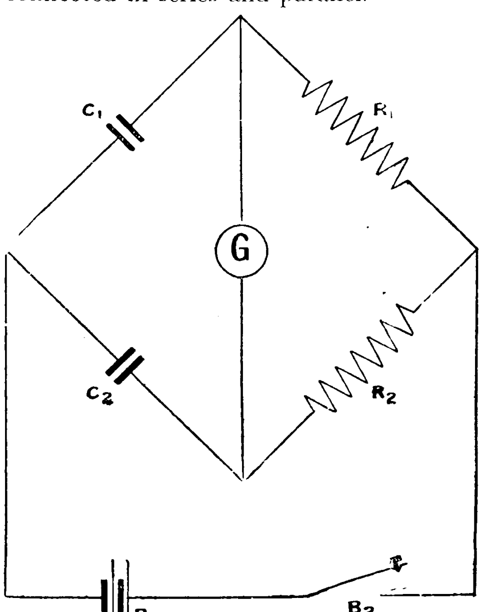
are C_1, C_2, C_3 . . ., we have, when they are in parallel,

$$C = C_1 + C_2 + C_3 + \ . \ . \ .$$

and in series

$$1/C = 1/C_1 + 1/C_2 + 1/C_3 + \ . \ . \ .$$

Figs 2 and 3 show how condensers are connected in series and parallel.



MEASURING CAPACITY

Fig. 4. De Sauty's method of measuring the capacity of a condenser is given diagrammatically

The capacity of a condenser may be found experimentally from that of a standard or known condenser by means of de Saüty's method. Fig. 4 shows the method of bridging. R_1, R_2 are two variable resistances, G a galvanometer, C_1, C_2 the two condensers, the value of C_2 being known. B_1 is a battery, and B_2 a battery key. The resistances are arranged so that when the battery key is depressed the galvanometer does not deflect.

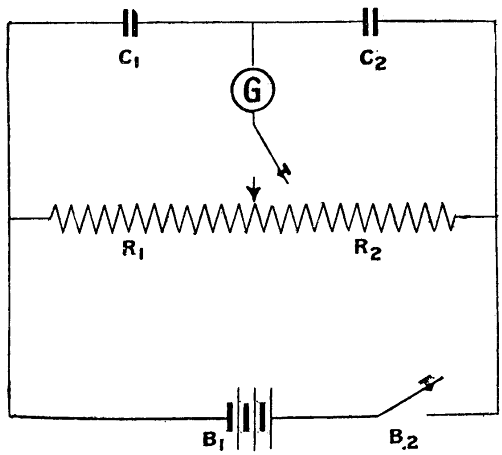
Then

$$C_1R_1 = C_2R_2$$

or

$$C_1 = C_2R_2/R_1.$$

By Lord Kelvin's method the terminals of a battery, B_1 (Fig. 5), are connected to two variable resistances, R_1, R_2, the two condensers are arranged as shown,



KELVIN'S CAPACITY MEASUREMENT

Fig. 5. Kelvin's method of measuring the capacity of a condenser is represented by this diagram

and a galvanometer connected across through a galvanometer key. When the battery key is closed the condensers are charged with opposite potentials, and when the galvanometer key is closed the galvanometer deflects suddenly. By keeping $R_1 + R_2$ constant, though varying them separately, a point will be found so that the galvanometer does not deflect on the successive depression of the keys, and we have

$$C_1R_1 = C_2R_2$$

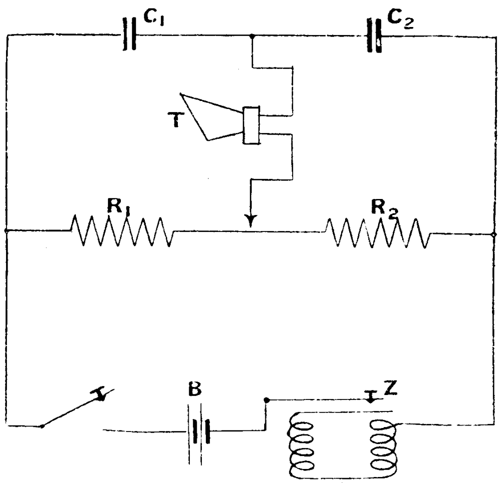
or

$$C_1 = C_2R_2/R_1, \text{ as before.}$$

The capacity of a coil is considered under the heading Coils.

The capacity of a battery is the number of ampere-hours it will function before the volts drop below the safe limit. The capacity of a battery depends on the rate of discharge, and falls off if this rate is increased. Thus a battery which gives 6 amperes for 10 hours will not give 12 amperes for 5 hours, but considerably less. —*J. L. Pritchard.*

CAPACITY BRIDGE. The capacity bridge shown in Fig. 1 is a most convenient circuit for comparing an unknown capacity against a known standard by the balance method, resembling the well-known Wheatstone bridge. Assuming, for instance, it is desired to measure the capacity of an unknown condenser value, such as C_1 in Fig. 1, the method adopted



COMPARISON OF CAPACITIES

Fig. 1. Known and unknown capacities can be compared by employing this circuit, which represents a capacity bridge, using a buzzer and a telephone

is first to join this in series with another condenser of known value, C_2. Both are then put in series with a small battery, B, and a buzzer or interrupter, Z, causing the battery to deliver an intermittent charging current to the condensers.

The remaining part of the circuit consists of a resistance R_1 and R_2, also a telephone, T, with a sliding contact upon R_1, R_2—that is to say, the condensers are shunted by this resistance. The two condensers being in series, the same charging current must flow through each, and the potential difference maintained by the battery, B, will be divided between them, according to their respective capacities. If between R_1, R_2 is a slide wire on a metre scale and contact is made somewhere along its length, the potential differences across the two sections on either side of the point of contact must necessarily be directly proportional to their respective resistances, and therefore to their lengths. The telephone connexion, T, on one side branches from the common junction between the two condensers, C_1 and C_2, and on the other side is capable of traversing the whole length of R_1, R_2.

On moving the adjustable contact, a point will be found at which no buzz is heard in the telephones, indicating an equality of potential on either side of the sliding contact. The bridge is then said to be in balance, the sliding contact being at the same potential as the other fixed connexion at the junction between the two condensers. Expressing this in symbols:

$$\frac{C_1}{C_2} = \frac{R_2}{R_1}$$

from which it follows that

$$C_1 = \frac{C_2 \times R_2}{R_1}.$$

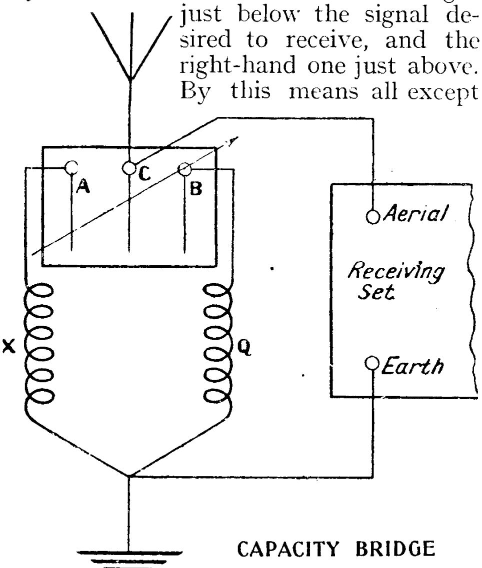
Sometimes the best possible adjustment on the slide wire does not lead to complete silence in the telephones, but this is of little consequence in taking a reading, provided a position can be found where the noise is at a minimum, with a distinct increase on either side of it. If, on the other hand, a continuous increase or decrease of telephone noise is found the whole way along the slide wire, it indicates that the difference between the unknown and known condenser capacities is too great to be compensated by the amount of resistance in R_1 and R_2, in which case the alternative is to couple up another standard condenser of different capacity greater or smaller than the one first tried out, and make another trial to obtain balance.

Or an extension resistance coil may be coupled in series with R_1, R_2, in order to bring the slide wire in the balancing range of adjustment. Capacities between 0·0007 and 0·5 mfd. can be dealt with on a metre slide wire consisting of No. 28 "Eureka" resistance and an extension coil of 0·85 ohm at each end of the metre wire. By adding a further extension of 20 ohms to the slide wire, the useful range can be increased up to 2 mfds.

While the capacity bridge in its pure form is a laboratory instrument for the determination of capacity by bridge methods, an application of it may be adapted with good results in ordinary wireless receivers. One of the best-known forms of capacity bridge is the three-electrode variable condenser, known as the 3 E.V.C., illustrated on page 479. It includes three tiers of vanes, each tier being independently movable, and capable of interleaving by rotation of the controlling knobs. Suitable scales and pointers indicate the relative positions of the electrodes. The controls of the two outer tiers are geared up so that a small movement of the knob generates a larger one in the vanes.

It is apparent that by a construction of this kind, in conjunction with suitable connexions, a bridge system can be obtained; for the amount of capacity obtained between one of the outer tiers and the centre one can be balanced by the other. This adjustment may be readily obtained by rotating the outer tiers towards or away from the centre. Final adjustment either way may then be made by rotating the centre tier.

While this condenser may be applied to a receiver in many ways, undoubtedly its greatest field of use to the amateur lies in its possibilities as a reducer of interference, either from static or unwanted signals. To fulfil this purpose, it is connected in conjunction with suitable inductances across the aerial earth system of the tuner of the receiving set. Each inductance is connected in series with an outside tier of the condenser, the centre tier being connected to the aerial. A diagram of this arrangement is shown in Fig. 2. A and B are the outer tiers, C the central one, and X and Q are the inductances. The ends of the inductances opposite to those which are joined to the bridge are connected to the centre tier, and the outer tiers interleave with it. There exist in effect two filter circuits, both tunable, in parallel, with a capacity coupling between each. The object of this arrangement is to tune, say, the left-hand circuit to a wave-length just below the signal desired to receive, and the right-hand one just above. By this means all except



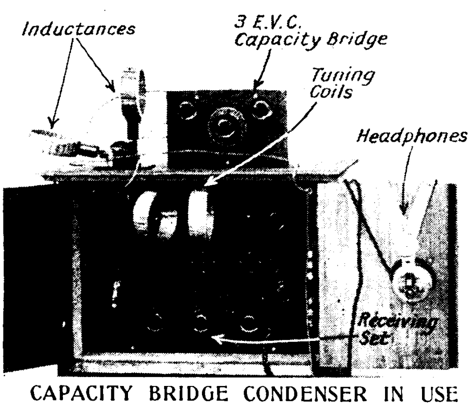
CAPACITY BRIDGE FILTER CIRCUIT

Fig. 2. The greatest service to the amateur of the three-electrode condenser consists in its use as a capacity bridge to reduce static and other interferences, the outside vanes being connected with inductances X and Q, as in the diagram

very powerful interference is eliminated, for the desired wave-length is shielded on both sides.

It must be noted that this apparatus is additional to the ordinary tuner of the receiver, as seen in Fig. 3, and does not take its place. If the left-hand circuit be the lower range filter, and the right the higher range, then the value of the inductance X will be 420 and of Q 600, for the broadcast wave-length band.

Considerable practice in tuning the device is necessary to achieve really good results, although its immediate application will cause an improvement in selectivity. In particular, when first applied, spark stations, which are a considerable nuisance to broadcast listeners in coastal districts, will be very much reduced in strength.



CAPACITY BRIDGE CONDENSER IN USE

Fig. 3. This photograph shows the 3 E.V.C. connected up with a three-valve receiver as filter circuit for reducing or eliminating interference from statics or spark and other unwanted signals

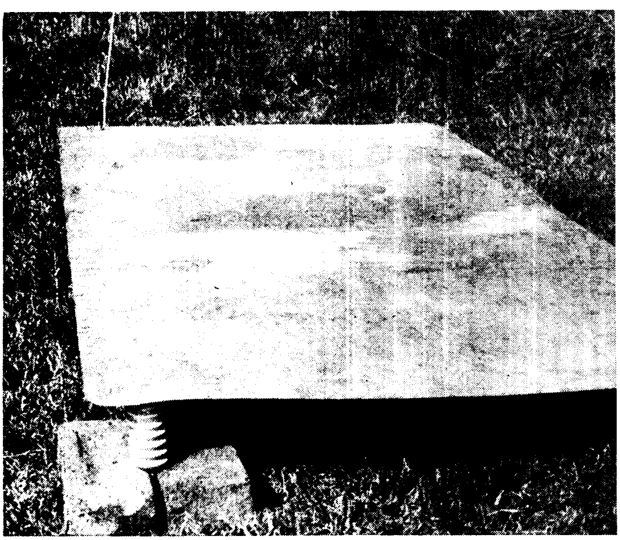
CAPACITY COUPLING. The coupling between two oscillatory systems due to capacity between points of the circuits normally at different potentials. *See* Coupling.

CAPACITY EARTH. In the early days of wireless installations "earths" were of a more or less primitive nature, but it soon became obvious from the difficulties encountered that something more than a single plate of metal buried in damp ground was necessary for transmission.

In ship installations, of course, the hull of the vessel itself provides an almost perfect earth, through the medium of the sea-water and the intimate contact it makes with it; but for land stations various means have been devised from time to time to get a really reliable and dependable earth not subject to variations with changes in climatic conditions.

When oscillatory currents are concerned a very large capacity or plate interposed between the aerial itself and the earth forms almost as good a connexion as though a buried plate had been employed in actual electrical continuity with the aerial. An arrangement of this kind would be called a capacity earth.

As represented in the figure, it consists of a large sheet of metal or metal gauze supported on insulators a short distance off the ground, from which it must be thoroughly insulated. This sheet is connected with the lead wire coming from the aerial. The other plate of this air condenser consists of the earth itself, and a capacity of such dimensions will offer practically no obstruction to high-frequency oscillations. Unless, however, there is a really good and suitable soil underneath, satisfactory working conditions cannot always be relied upon; and the buried earth system is in greater favour whenever it is possible to use it. For portable stations, of course, where the apparatus has to be moved about at short notice and set up quickly, a buried earth would be out of the question, and in such cases capacity earths are largely employed.



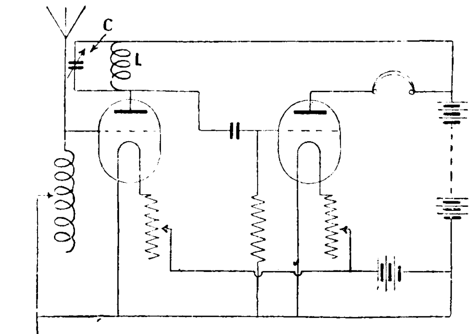
EARTH PLATE BETWEEN AERIAL AND EARTH

When it is not desirable to introduce an earth contact between aerial and earth, a capacity earth, such, for example, as the insulated metal plate in the photograph, can be employed

As a matter of fact, it is quite customary in these instances to employ wire netting or gauze, simply unrolling the sheets and laying them out flat on the ground, relying on the indifferent contact made by the relatively few points that actually rest on the earth to preserve the insulation, which it does in a more or less satisfactory manner. In modern practice a well-designed buried earth would consist of a ring of galvanized iron or zinc plates buried vertically to a depth of about three feet, with the top edges six inches or so below the surface. For a station of moderate power the diameter of this ring of plates would measure some fifty feet. Each plate is bolted to the others, and a stranded bare galvanized iron wire or cable is run below the surface of the ground from each plate to a central junction as near as possible to the transmitting plant.

If a river, well, or spring is available, extra plates would be buried in these situations, and additional connexions taken to the extension points. In high-powered stations it would be good practice, also, to provide a further set of earth plates immediately underneath the aerial itself, these plates being connected together and to the main earth in order to provide a path for the current induced in the earth lying just below the course of the aerial.

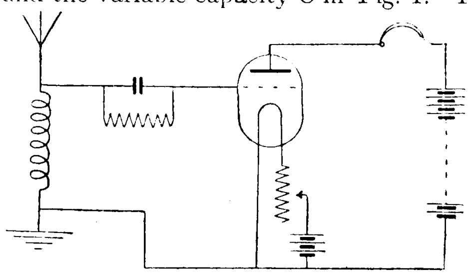
CAPACITY REACTANCE. Capacity reactance, more popularly known as "tuned anode," is a method of obtaining high-frequency amplification well suited for wave-lengths under 1,500 metres. Fig. 1 shows a typical circuit involving capacity reactance in a single-stage high-frequency and detector valve. L and C are respectively an inductance and a variable capacity in parallel to it. This tuning arrangement is placed in series with the positive of the high-tension battery and the anode of the high-frequency valve.



CAPACITY REACTANCE

Fig. 1. One high-frequency valve and one detector valve are used in the circuit above, which employs capacity reactance

Now, when the grid receives a series of oscillations, corresponding oscillations of the same frequency are impressed on the plate circuit. The object to be attained is to produce from these currents potentials capable of operating the next valve. This is done by the tuning inductance L and the variable capacity C in Fig. 1. It

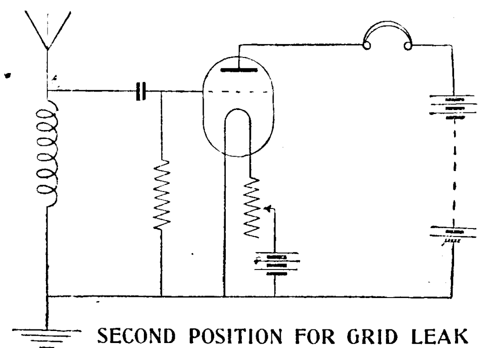


FIRST POSITION FOR GRID LEAK

Fig. 2. Placed across the condenser is the grid leak. This is a position frequently chosen in circuits of this kind. An alternative position is shown in Fig. 3

can be stated as a natural law that the impedance of a circuit is at its greatest value when that circuit is tuned. Thus, the tuned anode circuit of the high-frequency valve is capable of producing a very large impedance to oscillating currents. This produces a large decrease in anode voltage. The potential supplied by the high-tension battery is constant, so that the potential drop will occur on the anode of the high-frequency valve. Connexion is made from the anode of this valve through the customary grid leak and condenser to the grid of the second valve for rectification.

In the majority of receiving sets it is immaterial how the grid leak is placed. It can be placed straight across the grid condenser (Fig. 2), or, as in Fig. 3, from the grid side of condenser to earth, or in the case of a closed secondary circuit to low-tension negative. Figs. 2 and 3 show this, and a simple rectifying circuit for clearness of illustration. Using capacity reactance in high-frequency amplification, it is essential to connect up the grid leak as shown in Figs. 1 and 3—that is, from the grid side of condenser to low-tension negative or earth. It will be seen that if the grid leak is placed across the condenser, as in Fig. 2, a path will be found for the steady plate current to affect the grid with a strong positive potential. This would spoil the operation of the valve, as the grid should normally have a zero to negative potential.



SECOND POSITION FOR GRID LEAK

Fig. 3. Here the grid leak is placed between the grid and the earth, the condenser being in series with the grid and aerial lead

Capacity reactance coupling is probably the best method of coupling on wave-lengths under 1,500 metres. It has the disadvantage of being periodic—that is, it requires tuning to the wave-length of the station to be received. Compensating for this trouble, it has very good selectivity and sharpness of tuning. The following points must be noted.

The impedance of a tuned circuit may be expressed in the following equation:

$$Z = L/CR \text{ ohms,}$$

where Z represents impedance in ohms,
,, L ,, inductance in henries,
,, C ,, capacity in farads,
,, R ,, resistance in ohms.

Putting the above equation more simply into words, we have the impedance equals the inductance divided by the capacity and the resistance of the circuit. As we require to obtain a maximum impedance, resistance and capacity must be kept at a minimum. It is impossible to get a tuned circuit without these values R and C. Resistance can be cut down by using a large-gauge wire on the inductance at the expense of bulkiness against compactness.

Capacity, which is always present in an inductive circuit, can be minimized by the use of Litzendraht wire if a coil inductance is used. If basket coils are used, those known to have a minimum self-capacity should be chosen. Connecting wires should be of sufficiently heavy gauge to support themselves well away from the panel on which the circuit is mounted. The use of switches having large self-capacity should be avoided. The well-known Dewar telephone switch has an extremely high capacity, no sleeving being used. Connecting wires should be as short as possible and cross each other at right angles.

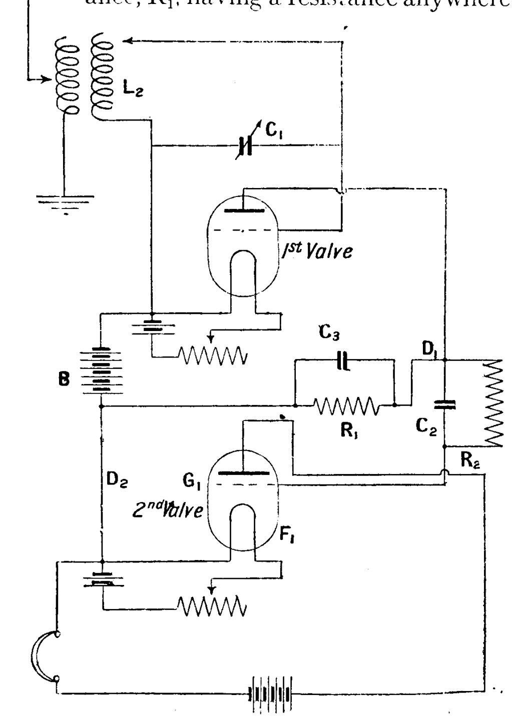
A small variable capacity is required to tune the circuit, therefore, if the self-capacity of the circuit has been reduced to a minimum a larger variable condenser may be used, giving a higher wave-length range.

It is important to point out in dealing with the impedance and resistance of the capacity reaction coupling that the impedance is the natural disinclination of the high-frequency oscillations to travel through a circuit where inductance is at a high value. At the same time the circuit offers only a comparatively small resistance to the steady anode current passing through it, and, therefore, no excess of plate voltage is required.

There is another use to which capacity reactance can be put. This consists of introducing a condenser, one side of which is coupled with the anode and high-tension positive of a rectifying valve. The condenser is then capacitatively coupled with a condenser in the grid circuit.

It may either be coupled with the grid condenser or to a fixed condenser in the aerial circuit. The object is to obtain a feed-back from the anode circuit to the grid circuit. In principle, its action is identical with the reaction coil. This difference, however, exists: whereas the reaction coil makes a magnetic coupling to the grid circuit, the condenser in the plate circuit makes a capacitative coupling. This coupling is very rarely used in modern circuits, for it has many drawbacks. The coupling is very small and inefficient and there is no means of variation. It cannot be placed in series with high-tension positive and anode, as it would prevent passage of steady plate current. It may be said that the magnetically coupled reaction coil has entirely superseded it. *See* Anode Circuit; Anode Reactance Coil; Reactance; Tuned Anode.

CAPACITY RESISTANCE. One of the drawbacks to the use of cascade amplifiers for radio-frequencies is the necessity for tuning the output and the input circuits of successive valves to the wave-length of the incoming signal, as a complete readjustment of all tuning elements is required whenever the aerial circuit is varied for reception of a new wave-length. The many complexities which this entails can be done away with by the Capacity-Resistance (or Resistance-Capacity) coupling illustrated in the diagram. This diagram shows a non-inductive resistance, R_1, having a resistance anywhere



COUPLING FOR RESISTANCE CAPACITY

Non-inductive resistance up to two million ohms is included in this circuit. By employing capacity resistance as here shown, complex systems of tuning are avoided in cascade amplifiers between 80,000 and 2,000,000 ohms, arranged in series with the plate battery, B. Across the terminals of R_1 are shunted the leads D_1 and D_2, which are connected respectively to the grid, G_1, and filament, F_1, of a second valve.

The operation is as follows :—During the reception of signals the radio-frequency currents impressed upon the grid circuit of the first valve, L_2, C_1, are repeated in its plate circuit, giving rise to a fluctuation of potential across the resistance, R_1. This in its turn acts upon the grid of the second valve and changes its potential in the same way and at the same frequency. The second valve may be adjusted to repeat without distortion, so that damped oscillations become audible. Audio-frequency currents may also be amplified in the same way.

Valves in Cascade

In order to prevent the plate potential of the first valve affecting the potential of the grid, G_1, of the second valve, a grid condenser, C_2, is connected in series with it as shown, and the grid circuit is further shunted with a leak resistance, R_2, consisting of two or three megohms. It is possible to connect any number of valves in this manner in cascade, and if care is exercised to choose valves having similar operating characteristics, no further adjustments in the circuits of the successive valves are required.

In order to tune this circuit to a distant receiving station the operator simply tunes the aerial circuit and the secondary circuit of the receiving transformer to that particular wave-length. Some very striking results have been obtained by amplifiers of this type ; it has been found possible to obtain current amplification up to one million with a five-stage amplifier arranged on these lines. An eight-stage amplifier is so sensitive that signals may be received without difficulty over distances of 4,000 miles with a frame aerial only five or six feet square. In some cases advantage is found in shunting the resistance, R_1, by a condenser, shown at C_3. *See* Cascade Amplification.

CAPACITY SWITCH. Any switch which has the function in a circuit of switching capacity in or out is called a capacity switch.

It as an unfortunate thing, as far as wireless is concerned, that all switches themselves must possess capacity. Stray capacity is a bad thing in wireless apparatus, and every effort on the part of the experimenter should be made to avoid it.

The ordinary capacity switch consists of two metal blades, long, narrow, and thin, rotating round a centre rod which carries the insulating knob or handle. The capacity switch is used to insert a variable condenser into the primary tuning circuit either to place the condenser in series to decrease the effective wave-length of the aerial circuit or to place the condenser in parallel to increase the effective wave-length. In another type of capacity switch the switch enables a number of condensers to be switched in at will. *See* Anti-Capacity Switch ; Bridging Condenser ; Capacity ; Condenser.

CAPTANCE. That part of the total impedance in a circuit due to capacity. It is also known as capacity reactance (*q.v.*). *See also* Impedance.

CARBON. One of the chemical elements. Its chemical symbol is C, atomic weight 12. Carbon is found in all animal and vegetable matter, in minerals, and in the form of carbonate is found in a large part of the crust of the earth. The wireless experimenter is largely concerned with carbon in some form or other as, for example, the blocks used in dry cells and other primary batteries. It is used in some forms of telephones and microphones and in the electric arc lamp. Natural carbon is found in two states, first as the diamond, which is pure carbon, and as graphite, common forms of which are named plumbago, black lead. Charcoal, a nearly pure carbon, and lamp black, also practically pure, supply fine carbon.

Carbon is a conductor of electricity, and for this reason the pencil lines drawn on some types of condenser serve as a leak for the current. The relative conductivity is ·019 at 0° C., silver being taken as 100. The relative conductivity of carbon in the form of graphite is ·062. Both figures are an average, as the conductivity varies with the composition. The resistivity is from ·06 to ·09 ohm per centimetre cube.

In some applications the carbon would offer too great a resistance, and to overcome this difficulty the surface can be electrolytically treated, depositing a skin of copper sufficient to give the needful conductivity. This system is used in

Fig. 1. Arc lamp carbons. They are made from lamp-black, prepared from creosote oil, and afterwards consolidated with tar and other materials, and baked in crucibles

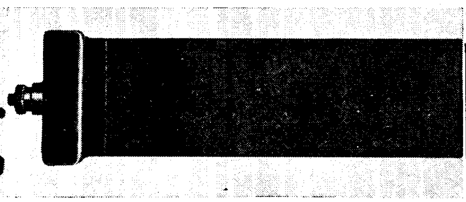


Fig. 2. Carbon for Leclanché cell. Carbon positive elements are used in this form, and are flat for insertion between the negative plates

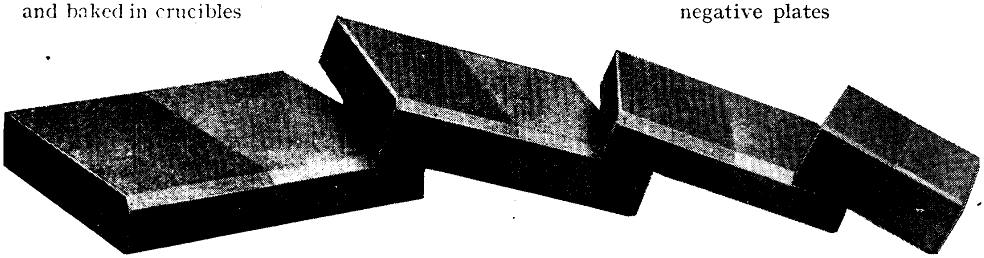


Fig. 3. "Henrion" carbon brushes as used in dynamos or electric motors. Their purpose is to make contact between the moving and the fixed parts

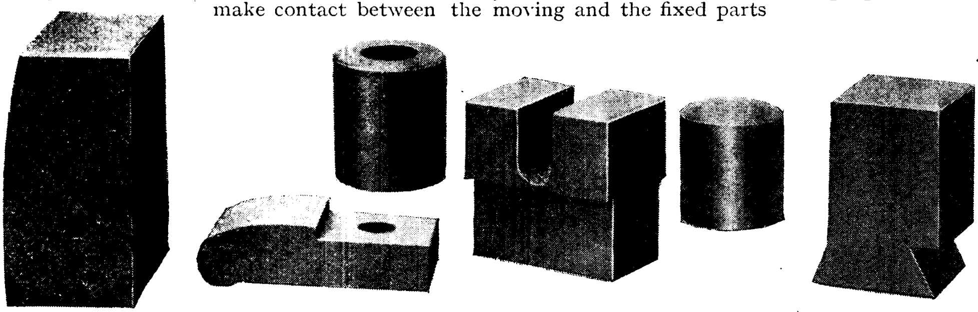


Fig. 4. Shaped "Henrion" carbon brushes. Various types of motors and dynamos require different shapes of brushes. Here are a few selected

Courtesy Siemens Bros. & Co., Ltd.

CARBON IN FORMS AS USED IN WIRELESS WORK

some makes of arc lamp carbons, and in brushes for dynamo and motor work. By another method a wire is embedded in the centre of the carbon during the manufacturing process.

Arc lamp carbons are long and relatively small in diameter. The general appearance is shown in Fig. 1. The positive carbon is usually thicker than the negative, and the diameter of the carbon is determined by the amperage to be dealt with. For a current of 5 amperes this may be 7 mm. for plain carbons and 12 mm. for cored carbons. The latter have a hollow in the centre of the interior, made during the process of manufacture. The purest material for arc lamp carbons is lamp-black made from creosote oil burnt under appropriate conditions. Other ingredients are added with a binder of refined tar or other material. The mixture is then pressed to shape and subsequently baked in crucibles, the temperature being slowly raised to the order of 1,200° C.

An extensive application of carbon is in the form of blocks used as brushes to effect contact between a moving member, such as the commutator of a dynamo or motor, and the fixed part of the machine, known as the brush holder (*q.v.*). These may be solid or a composite structure such as the Henrion, illustrated in Fig. 3. The processes of manufacture are such that the carbon can be pressed to any reasonable shape, and several examples are illustrated in Fig. 4, showing types of carbon brushes.

A most useful form of carbon is illustrated in Fig. 2, and is the type used in

Leclanché cells for the positive element. The upper part is provided with a terminal, the screwed part of which is embedded in the block during the manufacturing process. A number of cut carbons by the Siemens Co. are illustrated in Fig. 5, and show various types used in microphones and other wireless apparatus.

Pencil carbons and cut or plate carbons are shown in Fig. 6, and are used in various ways in wireless work for batteries and other purposes. The experimenter who needs small blocks of carbon can often obtain them from otherwise useless carbons from disused batteries, and can saw them to shape with an old and fine-toothed saw. Carbon can be scraped to a smooth surface and holes can be drilled with a cast steel drill operated with a hand drill stock or in the lathe. The material is somewhat brittle, and care has to be taken not to break it, especially when drilling and sawing. The point to watch is that the carbon be well supported immediately beneath the drill or the saw, as the case may be. Carbons for battery purposes are often copper-plated at the top to facilitate a good and sufficient electrical connexion. When this cannot be done the terminal ought to be attached to a substantial brass or copper strip in firm contact with the carbon. *See* Agglomerate Leclanché; Battery.

CARBON CLAMPS. Holding devices used in an arc lamp or other device employing carbons, generally in the form of rods. A simple system is illustrated in Fig. 2, and shows the two carbons side by side, and how they are held by the clamps, which are adjusted by turning the thumbscrew at the right. In a multiple-carbon arc lamp several sets of the clamps may be disposed as shown in Fig. 1. The construction of the clamps varies somewhat with different makers' practice, but for all of them there is provision for holding the carbon when it has been inserted, and for separate adjustment in order that all

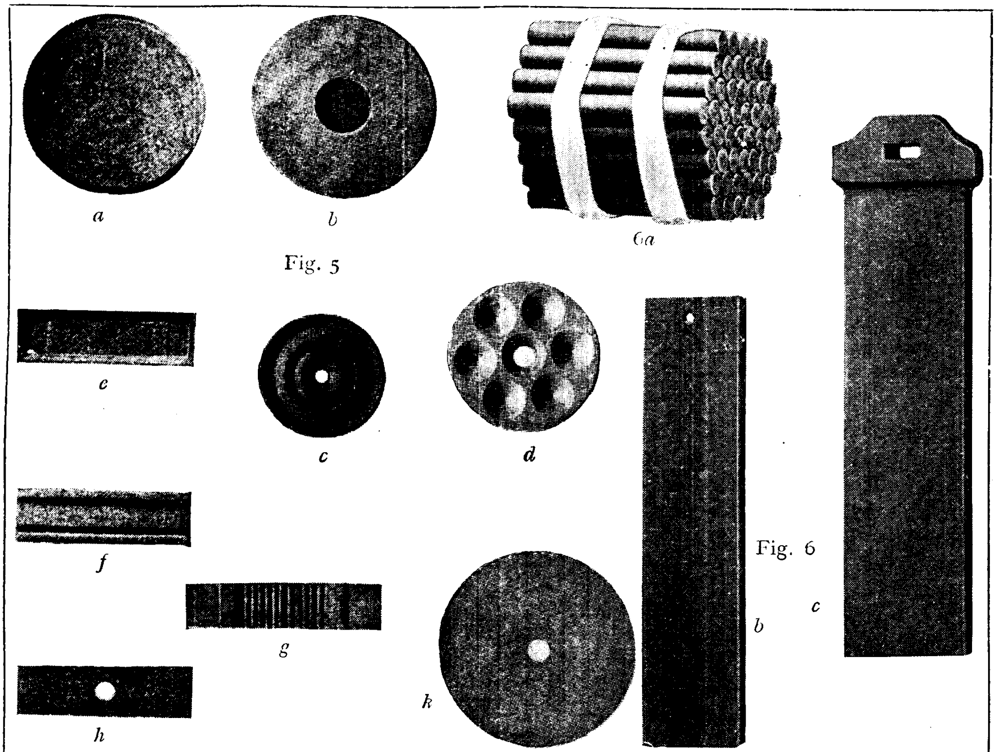
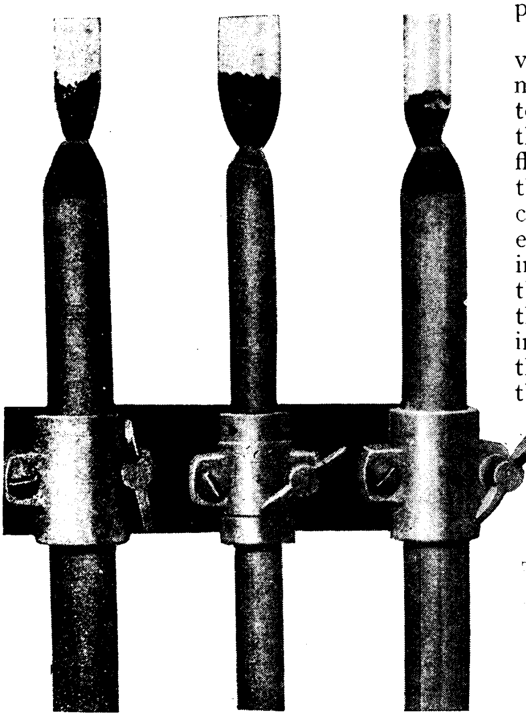


Fig. 5. On the left: *a*, *b*, and *k*, are diaphragms; *c* and *d*, microphone carbons; and *e*, *f*, *g*, *h* brush carbons. Fig. 6. On right: *a* is a bundle of pencil carbons; *b*, an example of flat battery carbon; and *c*, a carbon cut to shape as a battery element

Courtesy Siemens Bros. & Co., Ltd.

SPECIMENS OF CARBON PIECES FOR VARIOUS PURPOSES the carbons may be adjusted so that they make contact simultaneously. The mounting should also be so arranged that all the carbons can be simultaneously moved, and for this reason the clamps can be connected together as shown in Fig. 1, so that all travel uniformly for striking and regulating the arcs.

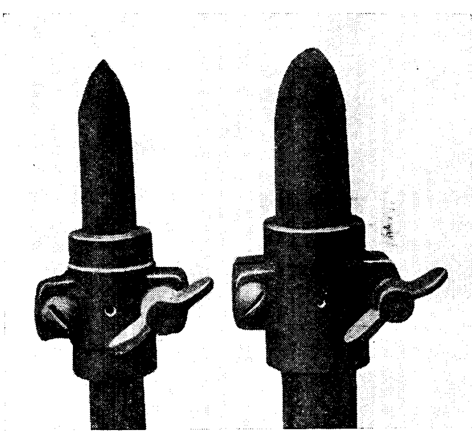


CARBON CLAMPS

Fig. 1. Multi-carbon arc lamp clamps are shown. In most of these arrangements the carbons may be adjusted separately, or a whole unit may be moved as required

CARBON DIAPHRAGM. Thin circular plate of carbon used in the telephone or microphone. The particular function of the carbon diaphragms in a typical transmitter is to act as the walls of a chamber containing granular carbon. One of the walls is attached to a metallic or other diaphragm which interrupts the flow of sound waves from the speaker's mouth, thereby agitating the carbon diaphragm and the granules between it and the rear diaphragm. The terminals of the transmitter are attached to the carbon diaphragms and a current passed through them from a battery or other convenient source of direct current supply. The resistance to the passage of the current from one diaphragm to the other is varied by the sound waves impressed on the external diaphragm, and the varying resistances set up variable electro-motive forces that correspond very closely to the original sound waves. The carbon diaphragms should have one of the faces highly polished to reduce the friction between it and the granules. *See* Microphone.

CARBON GRANULES. Finely pulverized particles of carbon used in a transmitting microphone and other apparatus to provide a mechanical means of varying the resistance of a current of electricity flowing through it. In a typical example the granules fill the space between two carbon plates so disposed that acoustical energy in the form of sound waves, when impressed upon one of them, agitates the carbon granules. Under this action they move slightly, thus varying the points in contact and varying the resistance to the passage of the electric current between the two diaphragms. The changes of the electro-motive forces thus controlled may be transmitted by wires or by wireless transmission to any convenient form of receiver. The granules are very fine. Another form of the granule

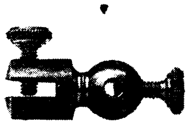


ARC LAMP CLAMP

Fig. 2. Carbons as used in arc lamps are here seen held separately in clamps which are adjustable by the thumb-screws

is that known as "shot," ground and polished to a spherical form. These are made in various sizes from 1 millimetre diameter. *See* Microphone.

CARBON PLATE CONNECTOR. Name frequently applied to a brass terminal adapted for attachment to a plate of carbon. One example is shown in the illustration, and comprises a body with an upper part having a terminal screw which grips the wire when inserted into the hole through the body. The lower part has a slot with a pinching screw that, when tightened, presses the connector into firm contact with the carbon plate. This type of connector is chiefly applicable for experimental purposes, and to the smaller sizes of carbon plate and for temporary use. The same terminal is convenient for other purposes, such as attachment to a bus-bar.



CARBON PLATE CONNECTOR

When carbon plates are to be connected a common method employed is the use of a slotted terminal-shaped piece of metal with an adjusting screw

CARBORUNDUM. Chemical product composed of silica and carbon, used as a crystal rectifier. It is produced by fusion, and the best type of carborundum crystal is green or bluish-grey in appearance. Dunwoody, in 1906, discovered that carborundum crystal had the power of rectifying high-frequency currents. Manufactured and prepared carborundum is well known for its abrasive and grinding properties. It is second in hardness to the diamond.

It has the property, that is to say, of passing a current of electricity in one direction only. It thus changes a high-frequency alternating current into a unidirectional pulsating current.

The curve in Fig. 1 represents a series of high-frequency oscillations. They are arranged about a line, x, x, which represents the normal condition of the conductor along which the current is flowing. The point *a* (Fig. 1) in the first half of the oscillation represents the greatest change from normal when in one direction, and *b* the maximum amount of current in the opposite direction.

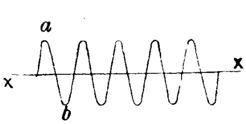
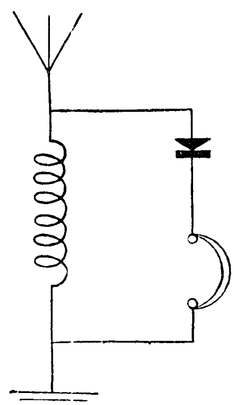


Fig. 1. High-frequency oscillations in carborundum theory

The frequency of these oscillations is so great that no vibrating armature, such as a telephone diaphragm, could possibly respond to them.

The function of the carborundum crystal is to allow these very rapid current fluctuations to pass in one direction only. This can be shown on paper by removing all the half oscillations represented below the line x, x in Fig. 1. The flow of current is now unidirectional pulsating, and this is capable of operating a telephone.

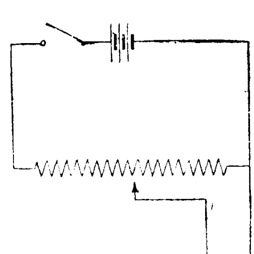
The resistance of carborundum is very high indeed, so that very poor efficiency would result from placing the crystal in series with the aerial or tuning circuit. The method adopted is shown in Fig. 2, where the crystal circuit is in parallel with the aerial circuit. Carborundum is found to be very much more efficient when a small direct current is flowing through it. Such current can be supplied from a two-cell accumulator or any three dry cells used in electric lighting or bells. Another curious feature of carborundum is that each specimen of the crystal works best at a particular voltage. This voltage ranges from 1½ volts to 3½ volts.



CARBORUNDUM CIRCUIT

Fig. 2. High resistance is offered by carborundum, and the crystal is placed in parallel with the aerial circuit

Regulation is effected by the use of a potentiometer. A potentiometer is merely a variable resistance, with, however, one important distinction. The wiring of a potentiometer varies the potential or voltage of the circuit without affecting the current flow to the extent that occurs in a variable resistance. Fig. 3 shows the wiring of a potentiometer. The battery is always in the circuit, therefore the resistance of the potentiometer must be high, about 200 ohms, in order that the battery cannot run itself down. A switch should be incorporated for breaking the battery circuit when the crystal is not in use.

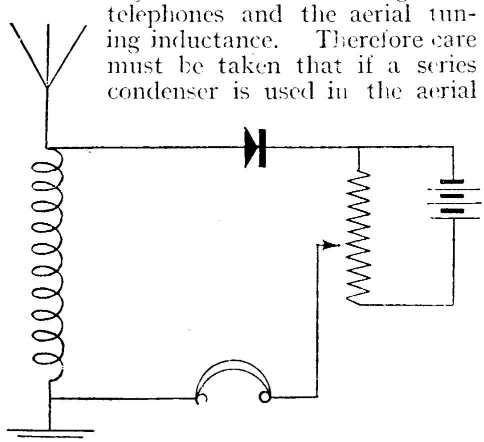


POTENTIOMETER FOR CARBORUNDUM

Fig. 3. Carborundum, when used as a crystal, should have a current passed through it regulated by a potentiometer

The method of applying the voltage to the crystal is not straightforward. If the potentiometer is placed across the crystal, the aerial oscillations will simply flow through it. To overcome this difficulty the potentiometer must be placed in series with the carborundum and the telephones.

It will be seen from Fig. 4 that the local battery currents run through the telephones and the aerial tuning inductance. Therefore care must be taken that if a series condenser is used in the aerial tuning circuit it must not be placed where it would stop this local current from flowing. A variable condenser does not prevent the flow of current ; but in a high-frequency oscillating circuit, having no metallic continuity, it prevents any flow of unidirectional current that the potentiometer battery will supply.



WIRING CARBORUNDUM CIRCUIT

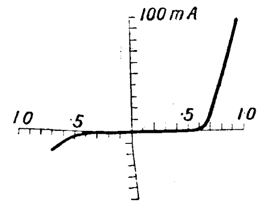
Fig. 4. Carborundum used as a crystal is in a circuit with a battery and potentiometer, the above being the wiring diagram

Carborundum, in common with all other crystals, should be used in conjunction with high-resistance telephones. Telephones are not chosen on account of the high resistance for work in conjunction with crystal receivers. The magnets of the telephones are wound with very fine wire in order to obtain a larger number of turns, thus increasing the power of the magnetic field. Naturally, the finer the wire and the longer it is, the greater will be the resistance. Hence the resistance of telephones is indicative of their efficiency for crystal reception if good conducting wire be used.

Carborundum, although giving more trouble than a crystal not requiring a battery and potentiometer, has advantages that outweigh the extra cost and trouble. Chief among these is its extreme robustness. It was used exclusively in the Army and Air forces during the Great War, where reliability was essential.

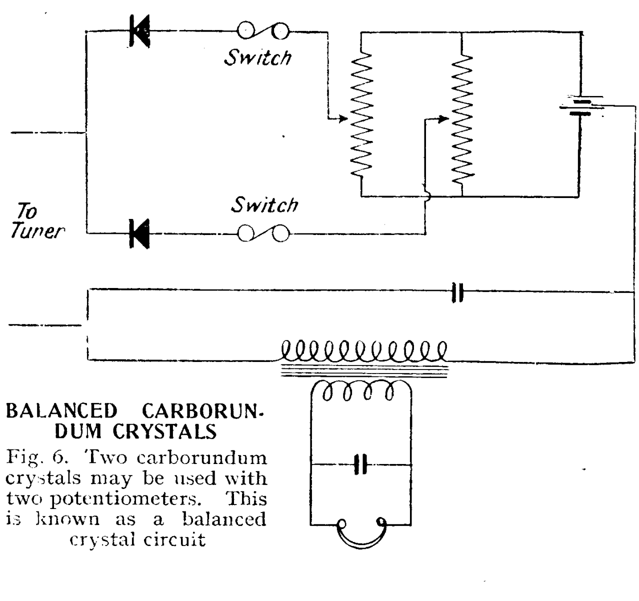
It was found to withstand vibration and gunfire where other crystals would be entirely useless. Carborundum seems to be sensitive in any part. It does not require a ball and socket adjustment, common to other crystals. A flat, springy strip of steel screwed down on to the top of the crystal is found to answer perfectly satisfactorily. Considerable pressure may be put upon the crystal without any prejudicial results to rectification.

Fig. 5 shows the characteristic curve for carborundum-steel detectors. It will be seen that the curve bends sharply upwards at about 0·7 volt. From 0 to 0·7 volt no current can flow at all, but after that point the current increases very rapidly for an increase in voltage. On the negative side the resistance of the combination is greater ; and as the voltage applied is increased, the increase of current is slower



CARBORUNDUM CURVE

Fig. 5. Carborundum-steel crystal detector theory gives a characteristic curve as above

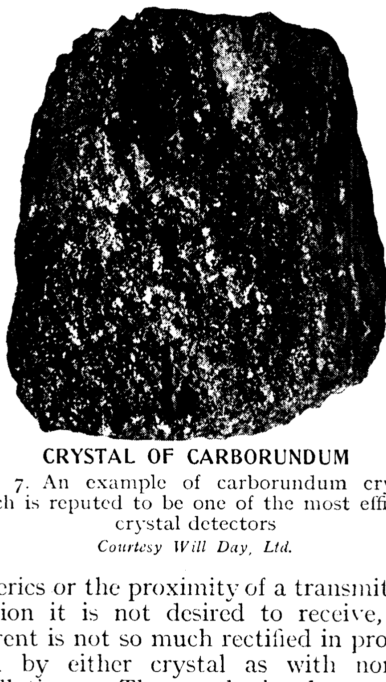


BALANCED CARBORUNDUM CRYSTALS

Fig. 6. Two carborundum crystals may be used with two potentiometers. This is known as a balanced crystal circuit

than on the positive side. The curve varies slightly with different specimens of carborundum, and can, therefore, only be taken as the general type of curve to be expected.

Fig. 6 shows a balanced carborundum crystal circuit due to the Marconi company. Two detectors are used and two potentiometers, so arranged that the crystals are rectifying in opposite directions. One crystal is adjusted to the most sensitive position, and the other to a less sensitive position. With normal signals the rectifying action is the resultant of the rectifications of the two crystals in opposite directions. When strong oscillations are set up, as for example, those due to atmospherics or the proximity of a transmitting station it is not desired to receive, the current is not so much rectified in proportion by either crystal as with normal oscillations. The result is that strong signals are largely balanced out, so increasing the efficiency for tuning purposes.



CRYSTAL OF CARBORUNDUM

Fig. 7. An example of carborundum crystal, which is reputed to be one of the most efficient crystal detectors

Courtesy Will Day, Ltd.

In adjusting such a circuit both crystals should be arranged at about equal sensitiveness, so that no sound is heard in the telephones. One crystal should then be gradually lessened in sensitiveness until normal signals come through with about the same strength as if only one crystal had been used. A switching arrangement may be provided so that one crystal can be cut out altogether when atmospherics are not strong or local interference is small.

CARBOY. A large glass bottle or container with a relatively narrow neck, used for the transport of acids. It is used in wireless for the transport of sulphuric acid. To comply with the requirements of railway and other transport organisations, it is protected on the exterior with a special form of wickerwork disposed as shown in the illustration. In some cases the basket may be composed of metal in the form of a crate, and some resilient packing material such as straw used to hold the bottle in place. The neck is closed with a stopper and sealed with wax. In view of the serious results that may follow an accident to such a vessel, the experimenter or others who handle a carboy cannot be too careful to protect it from any risk of breaking and spilling the contents.

SULPHURIC ACID CONTAINER

Carboys such as this are used for carrying the sulphuric acid commonly used in wireless work. It is a glass vessel protected against accidental spilling of its dangerous contents

CARDBOARD TUBE. Hollow, cylinder, relatively long and composed of laminae of paper united with a paste or cement. Cardboard tubes have many uses in wireless work, both in the industry and for the amateur constructor.

The materials used in their construction vary somewhat, and may include such things as straw, rag, paper pulp, wood fibre, and the like. As a practical matter it is difficult for the experimenter to distinguish the one from the other, as the exterior may be covered with a layer of paper. Points to look for are that the card be as homogeneous and close in grain as possible, of a uniform texture and thickness, and when the tube is pressed it should feel stiff and resistant. A spongy tube is difficult to handle, and is not such a good insulator. One of the great objections to cardboard tubes is that they are hygroscopic, and, therefore, in wet weather are liable to expand; while on very dry days the tube may contract so much that the diameter varies sensibly between the two extremes.

Owing to their lightness and ease of handling, and the nominal price at which they are obtainable, cardboard tubes are in extensive use for formers, whereon to wind many types of coil. Obtainable in numerous diameters, nominally varying by about $\frac{1}{8}$ of an inch, and ranging from about $\frac{1}{2}$ in. to 6 in. or more in diameter and some 24 in. or so in length, they can be purchased at most good-class stationers, or from dealers in wireless supplies. The experimenter will be well advised to lay in a stock of all likely sizes, say a range from 1 in. to 6 in. in diameter and all sizes that will just telescope one into the other. They are preferably stored in a vertical position in a bone-dry place, such as the top of a store cupboard by the side of the kitchen range.

It is most important to keep them absolutely dry, as if they get damp the insulating value is very low, and the material distorts readily.

Making a Cardboard Former

The insulating value is increased by treating the tube with resin, paraffin wax and other materials, as is described later. The first step is to cut the tube to the desired length.

To do this neatly place a piece of thick wood, such as a piece of curtain pole, through the cardboard tube, and of such a diameter that it fills the bore. Rest the whole flat on the table or work-bench, and draw a line around the tube at the point where it is to be cut. One way to do this is to hold the pencil steadily in the right hand and rotate the tube with the left, keeping the pencil in contact all the time. Another plan is to cut a piece of white paper to the length desired and sufficiently long to surround the card tube. Paste the ends of the paper and wrap it around the tube As soon as the paste has set the tube can be cut off to the edges of the paper, and when the work is complete the paper is pulled off.

To cut the tube cleanly without making a frayed and ragged edge is accomplished by means of a small brass-backed saw, as illustrated in Fig. 1. Hold the tube down on to the table with the left hand and cut it with the saw in the right. The purpose of the wooden liner is to provide a support for the card and to keep it from collapsing. Alternatively the tube can be severed with a pocket-knife, as shown in Fig. 2. The knife is worked around the tube steadily, gradually cutting into the tube, and taking particular care when nearly through to cut lightly and sever the card so as not to tear it. In most cases the tube will be wanted for an inductance coil, and it will be necessary to drill two small holes through the card near to the ends and some $\frac{1}{2}$ in. or so apart.

Finishing and Insulating the Tube

This is done with the tube supported on the wooden bar, and the holes drilled with a fine twist drill rotated at as high a speed as possible with the aid of a small hand-drill in the manner shown in Fig. 3. The tube meanwhile is held in place with packing pieces and a weight to keep it from moving. Should the tube be drilled in the lathe or under a drill-press, do not omit the wooden bar or the card will collapse as the drill is about to emerge from it, and a ragged hole will result.

The ends of the tube should then be well sandpapered with coarse paper and finished with fine, as illustrated in Fig. 4, and at the same time the ends can be sandpapered level, testing this by standing the tube upright on the bench on a smooth surface such as a piece of plate-glass and testing with a set square rested on the glass with the blade in an upright position. Care at this stage will save a lot of annoyance later, when the tube is to be fitted to a support or to the cheeks of an inductance coil mount.

To increase the insulation value the tube can be immersed and boiled in molten paraffin wax. This, in the case of all formers, can be accomplished with an ordinary saucepan in which the wax is melted and the tube left therein for a while, the wax being kept at the boiling point. The tube is then removed with the aid of a pair of pliers in the manner shown in Fig. 5, the surplus allowed to drain back into the pan, and the tube set in an upright position in a warm dry place to dry. Larger tubes can be treated in the

Fig. 1. By placing a wooden liner in this manner to prevent the tube buckling, a clean cut can be made with a brass-backed saw

Fig. 2. Another method of cutting a cardboard tube evenly through is with a sharp penknife, which does not fray the edges

Fig. 3. Holes should be bored in a cardboard tube in this manner for the ends of an inductance coil to pass through

Fig. 4. Sandpapering a cardboard tube. This ensures a smooth and level finish

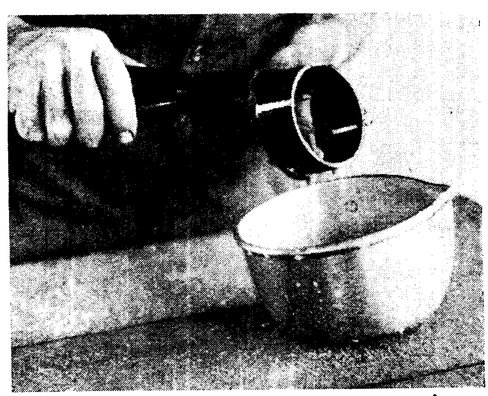


Fig. 5. Molten paraffin wax is prepared, and the former, held by pliers, as in the illustration, is dipped in the bath

CONVERTING CARDBOARD TUBES INTO FORMERS FOR COILS same way by using an old biscuit tin. Sterling varnish diluted with about one-third of benzine can also be used. The tube is well soaked in the solution and then baked in a slow oven for several hours. It is then finished with a coat of the varnish. Another good method is to coat the tube with any asphaltum paint, or with brunswick black diluted with turpentine. This makes one of the best and cheapest stains, from light brown to black, according to the amount of turpentine used. Several separate coats should be given, and the material allowed to soak in thoroughly, the tube being afterwards well baked.

While treating a tube in this way, it tends to collapse. The only thing to do is to support it in some way, as, for instance, with a block of wood covered with several layers of soft paper. The paper is necessary because the tube will contract and the wood could not be removed by sliding it out, but the soft paper will readily tear away and release it. Another method is to use a glass bottle of suitable size, and when the tube is finished break the bottle.

An excellent treatment for tubes is to cover them on the outside with linen well soaked in thin shellac varnish, or other insulating varnish. The card tube is well baked, and while warm the whole is covered with thick shellac varnish, generally known as stick varnish. The linen is then wrapped around the tube and worked with the fingers into close contact, as shown in Fig. 6, the ends overlapped about an inch and any surplus cut off. The linen is then smoothed and pressed into perfect contact and the whole given a coat of shellac varnish. The job is a distinctly messy one, but when the tube has dried it is remarkably stiff and the projecting ends of the linen at the ends of the tube can be cut off flush and the whole sandpapered with fine grain old paper.

The mounting of a cardboard tube to a panel or base is not a difficult process, but is one that lends itself to all manner of treatments. Some practical methods are dealt with as suggestions. For experimental work the tube can stand upright on the table or be fixed by a screw through a wooden cross-bar attached to the bottom of the tube. The simplest

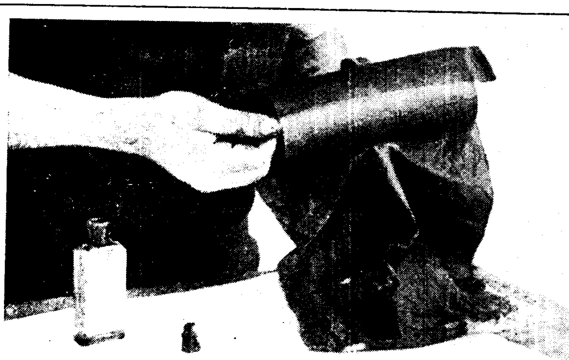


Fig. 6. Linen soaked in thin shellac varnish is being used to cover the cardboard tube

Fig. 7. How a cardboard tube is fixed on to saddles of wood as supports

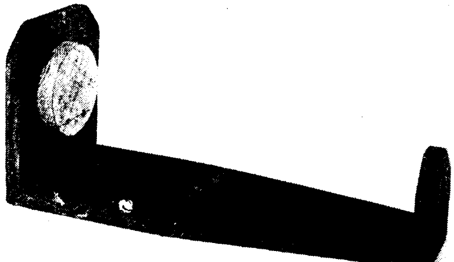


Fig. 8. One way to support the tube for a loose coupler is here shown. Note the circular cheek

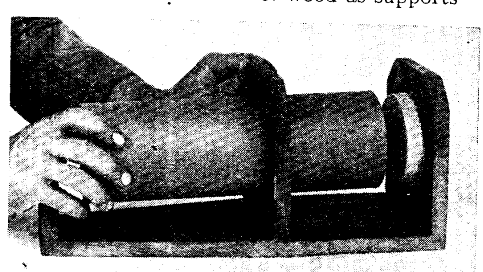


Fig. 9. In the middle of the frame seen in Fig. 8 a guide is erected and the cardboard tube inserted

LOOSE-COUPLER CARDBOARD TUBE FORMERS

Fig. 10. Bolts and nuts passed through a baseboard, or panel, form a secure means of holding a tube. Note the distance pieces between the tube and the panel

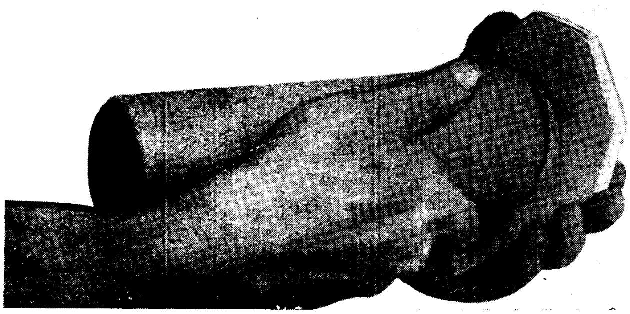


Fig. 12. After the recess is made, the cardboard tube is held as shown and gently pushed home, care being taken not to apply such force as to damage the tube

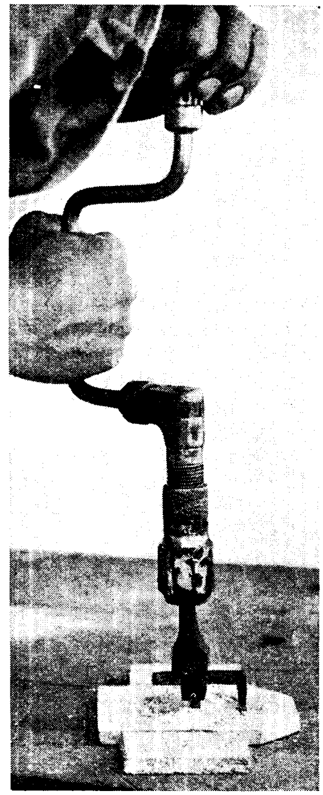


Fig. 11. By cutting an annular groove in this manner in the face of an end cheek, a recess is made for a tube to be fitted

METHODS OF MOUNTING A CARDBOARD TUBE FORMER

way is to make a baseboard of wood, and thereon to screw two saddles of wood about $\frac{1}{2}$ in. thick, and hollowed on the top to the same radius as the tube, and then to screw the tube to them with round-headed brass screws, as illustrated in Fig. 7, placing a washer beneath the head of the screw to increase the bearing surface.

When the cardboard tube has to be affixed to a vertical piece or cheek, as, for instance, the end of the stand, for a loose coupler, a simple plan is to cut a disk of wood of a size to fit nicely into the bore of the tube, and fix this with brass screws to the cheek, as shown in Fig. 8. Should the tube have to be supported by two uprights, one at each end, the same method can be adopted, but one end of the tube is fitted with a plug of wood, and this is secured about $\frac{1}{8}$ in. in from the end with glue, and a few fine brass screws. The other end is placed over the disk on the cheek, the tube coaxed into place, and then fixed with screws passed through from the outside of the cheek into the fixed wood plug.

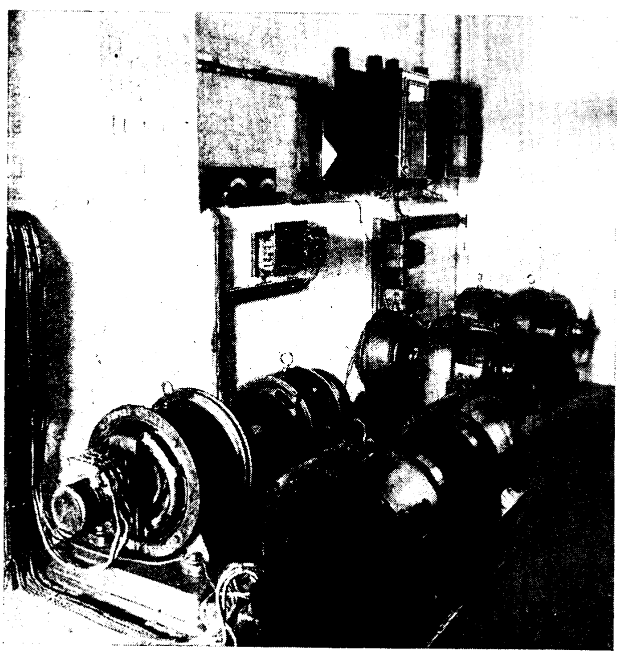
The purpose of fixing the plug to the tube is to enable the screws to bite into it, and by letting it rest within the end of the tube the edges are drawn up tightly to the face of the cheek. When one tube has to slide into another, as in the loose coupler, the outer or open end can be supported by an upright of wood with a hole through it equal in diameter to the outside of the cardboard tube, Fig. 9. It will not need special fastening at this point if a slider is used connecting the tops of the uprights. Otherwise, make all secure with a few fine screws driven through the cardboard into the wood.

Another neat fixing suitable for back of panel mounting is shown in Fig. 10, and consists merely of bolting or screwing the tube to the panel and disposing distance pieces of ebonite tube between the face of the panel and the tube to act as spacers to keep the tube the desired distance from the panel. Various other treatments for the mounting of tubes on to plug-in coil holders, the fitting of bushings to them when making a variometer and other devices, are dealt with under the headings of those articles, to which reference should be made. An excellent method that is easily carried out with a brace and bit is shown in Fig. 11, where an expanding bit is shown in use cutting a groove or annular ring in the cheek for an inductance coil. The bit is adjusted to the requisite diameter and manipulated in the usual way. The tube is then fitted to the groove, as shown in Fig. 12, and should be a nice snug fit. The fit will be self-supporting, and only needs a touch of glue to hold all secure. *See* Coil ; Crystal Receiver ; Inductance Coil ; Variometer.

CARDIFF BROADCASTING STATION. The Cardiff Station of the British Broadcasting Company was opened on February 13th, 1923. The studio and offices, somewhat restricted as to space—the studio measures 17 ft. by 17 ft. only—are in Castle Street. The power station and aerial are about a mile distant, in Eldon Road. The technical equipment differs little, if at all, from that of other stations. The transmitting plant consists of two motor-generator sets driving a motor-alternator, the alternator delivering alternating current at 500 volts and at a frequency of 300 cycles per second to a power transformer.

The secondary of the transformer supplies current at high voltage to the rectifier panel, where it is rectified and delivered as direct current at a voltage of 10,000 to the three panels, termed respectively independent oscillator, power oscillator, and modulator. The power oscillator delivers the continuous-wave oscillations to the aerial, the grid of the main oscillating valve being driven independently from the independent oscillator, thereby maintaining stability of wave-length. The valves on the modulator panel are controlled by the speech and music, which are received by landline from the studio, and thereby modulate the outgoing oscillations from the aerial.

The character of the programmes broadcast from the Cardiff Station are of particular interest in that, from the outset, the station has acted as a pioneer in several directions. The policy adopted has been the aim of giving the public only the best in every category, from musical comedy and revue to grand opera and Shakespeare: to lead public taste and not to follow it. Unlike the Midlands and North, orchestral music is not well known in the West Country and Wales. It is asserted by several distinguished musicians that 5 W A has revolutionized musical taste in the West. Not only are the outstanding works of the great masters regularly performed, but British composers are fully represented, even to the initial production of native grand operas. Further, all works are presented with adequate verbal explanations, tending towards full appreciation, and each concert is carefully arranged around some central idea.



CARDIFF BROADCASTING STATION

Fig. 1. Here is shown the generating plant, which includes two motor-generators driving a motor-alternator, whence alternating current is supplied to a power transformer

On literary nights, illustrated series have been given of the English poets from Chaucer to Masefield ; all

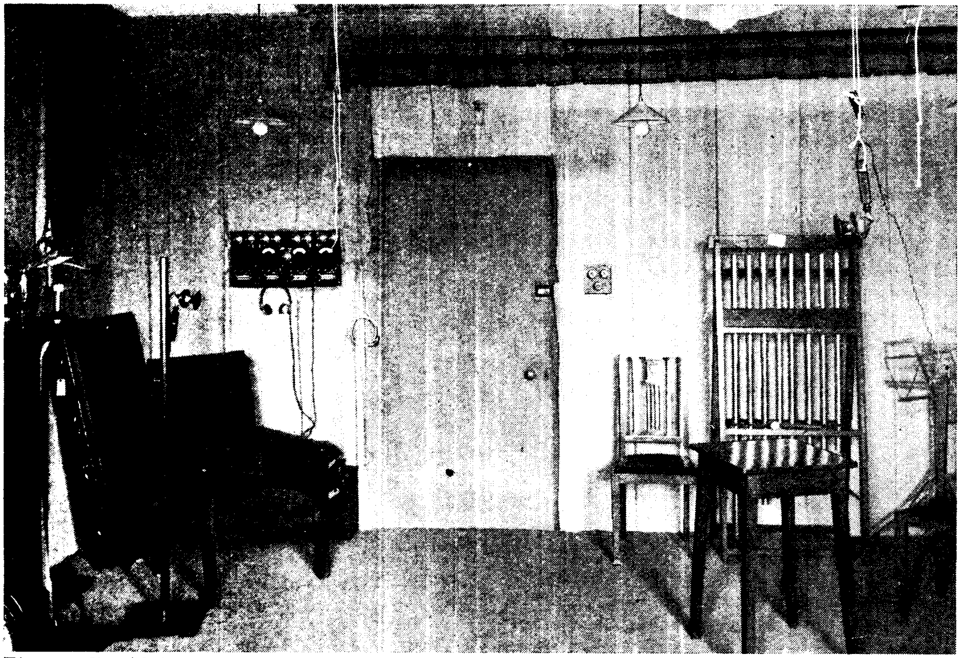


Fig. 2. Rapid improvements have been made in every broadcasting station, and the Cardiff centre is thoroughly well equipped. This photograph shows one corner of the 17 ft. by 17 ft. room where the performers broadcast the daily transmissions

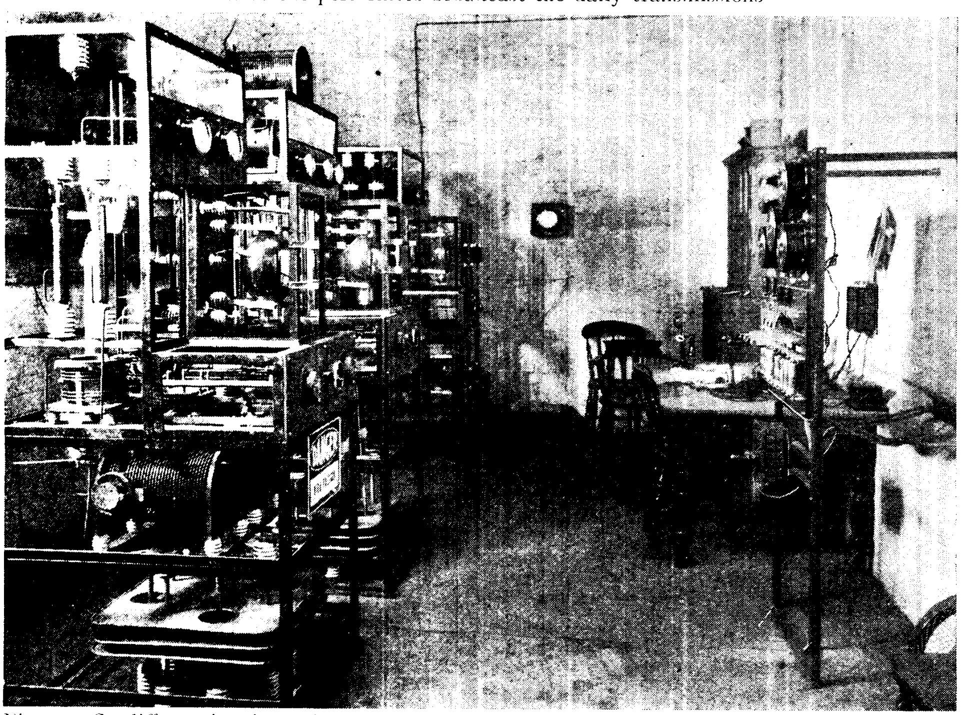


Fig. 3. Cardiff station is equipped with the Q type telephony transmitter, which is seen in the photograph. Operation is carried on in much the same way at all the B.B.C. stations, and the mechanical manipulation, control of output, modulation and methods of signalling fluctuations in strength or weakness of signals is no less an art than the actual broadcasting

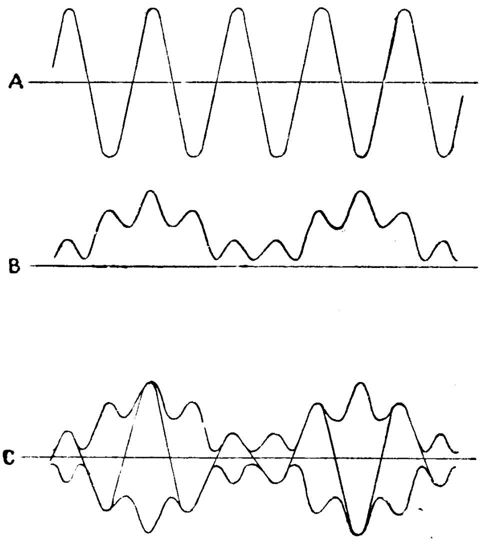
CARDIFF STATION OF THE BRITISH BROADCASTING COMPANY

Shakespeare's plays are presented by the station repertory company; old English comedies and many modern plays have also been given.

In view of the Welsh predominance in part-singing, Welsh choirs or glee-parties give regular recitals. It is found, however, that these do not transmit well, and the number of performers has to be strictly limited. A male voice quartette gives the best results.—*A. Corbett-Smith.*

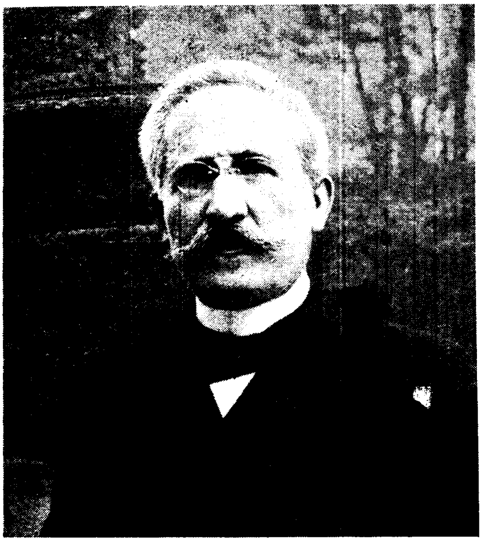
CARPENTIER, JULES. French wireless expert. Born in Paris, in 1851, he joined the Ecole Polytechnique in 1871, and in 1876 was appointed principal stores engineer of the Lyons Railway Company, making a special study of electricity. For his work in electricity he obtained in 1881 the cross of Chevalier of the Legion of Honour. One of the early pioneers of wireless in France, he founded the Compagnie Generale Radiotelegraphique, afterwards absorbed in the Compagnie Generale de Telegraphie sans Fil. Carpentier is a member of the Academie des Sciences, Commander of the Legion of Honour, and president of many scientific societies.

CARRIER WAVE. The wave corresponding in frequency to the continuous oscillation used in telephonic transmission, which is modulated during transmission of speech. In continuous-wave systems of wireless transmission the incoming continuous wave is modulated by having superimposed on it another wave which differs from it slightly in frequency. The carrier wave is sent out continuously while transmission is taking place, and the slight variations in its amplitude are produced by inserting a microphone in the circuit. The frequency of the carrier wave depends on the tuning of the transmitting circuit, and the receiving circuit is tuned to the same frequency in order to receive the signal at the maximum strength.



MODULATION OF CARRIER WAVES

Carrier waves are modulated from the pure condition, A, by imposing upon them waves representing sound vibrations of speech, B, thus producing the waves, C, which make speech audible



JULES CARPENTIER

Pioneer of wireless telegraphy in France and president of many French scientific societies. He founded the General Radiotelegraphic Co. of France

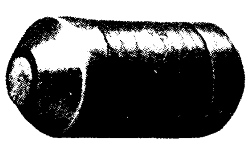
The figures show how the carrier wave is modulated: A shows the pure carrier wave, B the wave representing the sound vibrations of speech, and C how it is imposed on A to modulate it to produce a corresponding wave in the receiving instrument, and so speech.

CARRYING CAPACITY. The amount of current which a conductor can carry without becoming overheated. Heat is developed whenever an electric current flows through a conductor, and the amount of the heat is directly proportional to the resistance of the conductor and the square of the current flowing. If the heat develops faster than it can be dissipated, the temperature of the conductor rises.

In the case of the filament of a valve, for example, the heat generated by the flow of the current is sufficient to make the filament glow. The heating of conductors by exceeding their carrying capacity is made use of in the incandescent lamp, in electric heaters, etc. To protect circuits from currents exceeding their carrying capacity, a fuse is generally inserted in the circuit. These fuses are usually of the form of short wires or fusible metal plates or rods which melt at a comparatively low temperature. *See* Cartridge Fuse; Fuse.

CARTRIDGE FUSE. Form of fuse in which the fuse wire is surrounded by some non-inflammable substance enclosed in a cartridge-like tube. A fuse is a means of automatically breaking a circuit should the current in that circuit rise to a higher value than that for which it was designed. In wireless work, for instance, it sometimes happens that the high tension is by accident connected to the low tension terminals, the result being that, owing to the higher pressure, too much current goes to the valve filaments and they burn out.

It is this very heating effect of the electric current which is utilized in the fuse, for all that a fuse consists of in its essentials is a piece of wire of a metal having a low melting point inserted into the circuit. Directly the current heats it too much it melts, and so breaks the circuit. The actual size of the wire is chosen so that it melts before any other apparatus in the circuit can be damaged.



CARTRIDGE FUSE

Fig. 1. Contact is made in this type by the brass ends engaging the spring clips which hold it in position

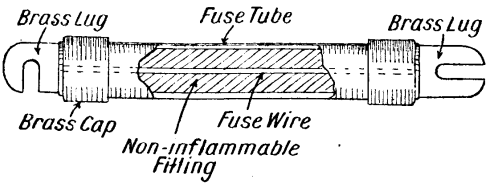
It will be realized that the fuse is thus an absolutely certain cut-out device, and, moreover, is very cheap to manufacture and maintain; but it has the disadvantage that a certain amount of danger from fire exists. To obviate the danger from fire, fuses are usually enclosed either in a porcelain or an iron cover, the latter being known as "ironclad" fuses.

The cartridge fuse is enclosed in a cartridge or sheath of some heat-resisting and non-conducting substance with a metal cap at either end. When the fuse blows, a complete new cartridge is inserted. The design of the fuse holder, however, is such that only a certain size of fuse may be inserted. This eliminates any chance of risk arising from the fitting of a wrong-sized fuse.

In a cartridge fuse the fuse wire or strip is enclosed in an outer cylinder, the space between the two being filled with a dust or powder of some non-metallic, incombustible material. This dust, to a very large extent, prevents the formation of an arc, which is always present at the sudden interruption of an electric current.

The ends of the wire are fixed to the metal caps, which are in turn clipped to the fuse holder. Many such fuses have very much the appearance of a large, stumpy grid leak, as will be seen in Fig. 1.

For work in which a fuse of absolute reliability is concerned, the only wires really suitable are copper and silver. When copper is used, the current required to blow the fuse must not exceed twice that of the normal full load current. This is quite a safe rule, and affords adequate protection to wiring, etc., in most cases.



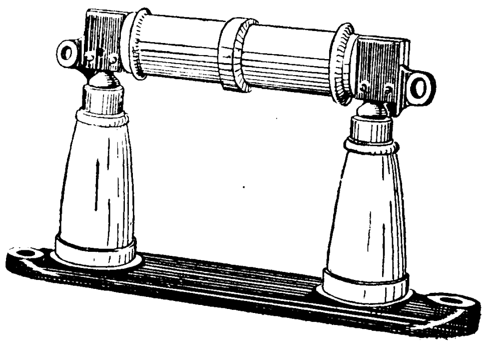
ALTERNATING CURRENT CARTRIDGE FUSE

Fig. 2. Fuses of this kind are used on alternating current switchboards. Contact is made by the flat slotted brass lugs

With silver, however, investigation shows that the fuse may be run for much longer periods at a temperature nearer to melting point than copper. This must not be taken to imply that silver will "run" at a lower temperature than copper, but that it will stand prolonged heating at high temperature with safety.

However, in most instances, the much higher cost of silver does not make this feature worth while. Some of the larger cartridge fuses have a hole cut in the outer container, which is sealed by a piece of thin paper. This enables a blown fuse to be discovered easily, for the action of the fuse forces the paper out, cracking it, and allowing some of the dust inside a free exit. This feature is very useful where two fuses are side by side, one on each side of a main supply.

Figs. 2 and 3 show sections of two typical cartridge fuses. Fig. 2 shows the type of fuse used on an alternating current switchboard. The fuse wire is in the centre of a fibre tube filled with asbestos or sand. The tube is fitted with two brass caps and brass lugs. Fig. 3 shows a high-tension cartridge fuse. It contains several wires which are soldered on to metal rings cemented into porcelain bodies. The cartridges are filled with



HIGH-TENSION CARTRIDGE FUSE

Fig. 3. Several wires soldered on to rings cemented in porcelain bodies are contained in the above cartridge, which is a high-tension fuse

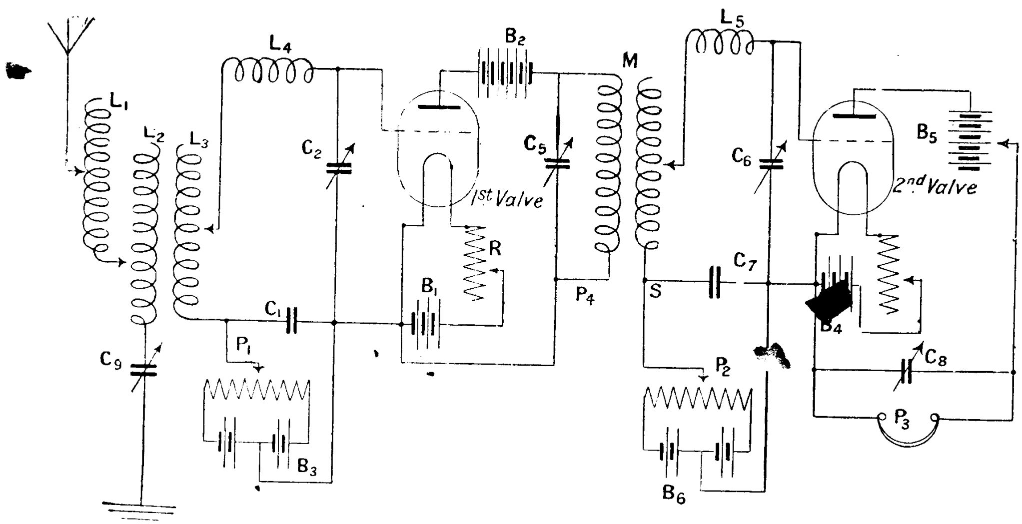
powdered mica, and are closed at each end with elastic membranes. These latter take up the pressure when the fuse blows.

CASCADE. Term applied to a number of Leyden jars or any pieces of apparatus connected up in series. In cascade amplification valves are so arranged in their circuits that each valve amplifies the output of the preceding one in the series.

CASCADE AMPLIFICATION. Owing to certain peculiarities in the characteristic curve of the three-electrode valve, a current of any wave train impressed upon the grid circuit may be repeated with amplification in the plate circuit, the degree of amplification depending upon the part of the characteristic at which the valve is being worked.

This amplifying or relaying effect is produced by reason of the ability of the valve to exhibit a larger variation of current in the plate circuit than the energy impressed upon the grid circuit. The electrons emitted by the heated filament are extremely responsive to the influence of positive or negative electrostatic fields, and amplification is readily obtained at radio-frequencies or audio-frequencies.

In the first method the potential of the grid in respect to the filament may be maintained so that a positive charge impressed upon the grid will cause a large increase in the plate current, while a negative charge causes only a small decrease of the plate current. It is equally possible to obtain the reverse effect by working the valve at some other point on its characteristic, but in either use the effect over the direction of a wave train is to impulse the telephone once for each group of incoming waves with what amounts to a rectified current.



CONNEXIONS OF TWO-VALVE RECEIVER BUILT FOR CASCADE AMPLIFICATION

Fig. 1. Radio-frequency amplification on the cascade system is produced in this circuit. This diagram may be used as a guide for construction. The coupling transformer M causes the radio-frequency of the plate circuit of the first valve to be introduced to the grid and filament of the second valve

In the second method the plate current is made to vary at audio-frequency by placing a condenser in series with the grid. The natural valve or rectifying action between the grid and the filament causes the incoming groups of radio-frequency waves to be rectified, and the grid condenser receives a unidirectional charge for the period of the wave train. As the condenser becomes charged up the actual flow of current decreases, but upon the termination of the wave train the condenser charge leaks out and the plate current returns to its normal value again.

Valves may be connected in a number of different ways for further amplification of incoming signals. One method is to impress either the radio- or the audio-frequency component of the plate current of one valve upon the filament and grid circuit of a second valve, that is by cascade amplification, the principle being to double the output circuit of the first valve to the input circuit of the second, and so on with as many valves as considered desirable.

As many as half a dozen valves may be coupled up in cascade, but it is questionable whether the resulting advantages compensate for more than half this number in ordinary practical operating conditions. The complete circuit connexions of a cascade radio-frequency amplifying system will be found in Fig. 1. Here it will be seen that the coupling-transformer M, with its windings P_4 and S, serves to impress the radio-frequency component of the plate circuit of the first valve upon the grid and filament of the second valve; that is, the output circuit of the first valve is coupled to the input circuit of the second valve, which is the condition essential for cascade connexions.

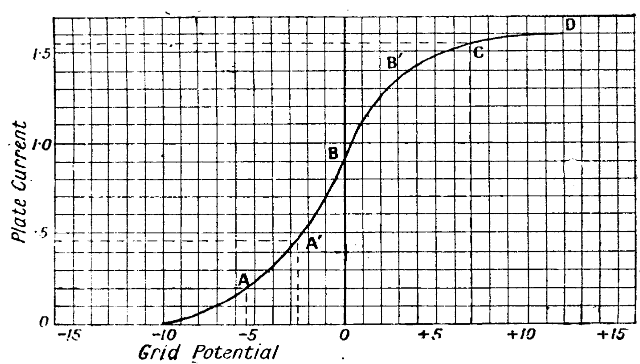
The aerial circuit as shown includes the loading inductance L_1, the primary winding of the receiving transformer L_2, and the variable condenser C_9. The grid circuit consists of the secondary coil L_3, the secondary loading inductance L_4, the shunt secondary condenser C_2; there is also a fixed condenser C_1, which shunts the potentiometer P_1, the latter having a resistance of 400 or 500 ohms.

The battery B_3 may be varied between 3 and 20 volts; B_1 is the usual 4-volt or 6-volt filament battery, and B_2 the high-voltage battery for the plate circuit of the first valve. The plate circuit also includes the radio-frequency circuit P_4 C_5.

The circuit for the second valve is as follows: L_5 is the loading inductance for the grid circuit, S the secondary coil of the transformer M. The shunt secondary condenser is shown at C_6, while the condenser C_7 performs the same function as C_2 in the first valve. The plate circuit of the second valve comprises the battery B_5, the head telephone P_3, and the shunt condenser C_9.

To follow clearly the method on which this system operates, it is necessary for the moment to refer to the phenomena exhibited by the characteristic curve of the three-electrode valve, illustrated in Fig. 2. From this it will be clear that large variations of plate current may arise from small deficiencies in grid potential, the magnitude of the variations bearing a close relation to the working portion of the curve. It is assumed for example that the potentiometer P_1 of the first valve is so adjusted that the grid potential is approximately at the point A on the lower end of the curve.

When the signals received are relatively weak the grid potential will increase or decrease by only a very small fraction of a volt. As the curve shows, under these conditions an approximately equal increase or decrease of plate current is the result, and since this is taking place at



PHENOMENA OF THREE-ELECTRODE VALVE

Fig. 2. Cascade amplification can be more easily understood by studying this curve, which is a grid-potential plate-current characteristic curve of a three-electrode valve

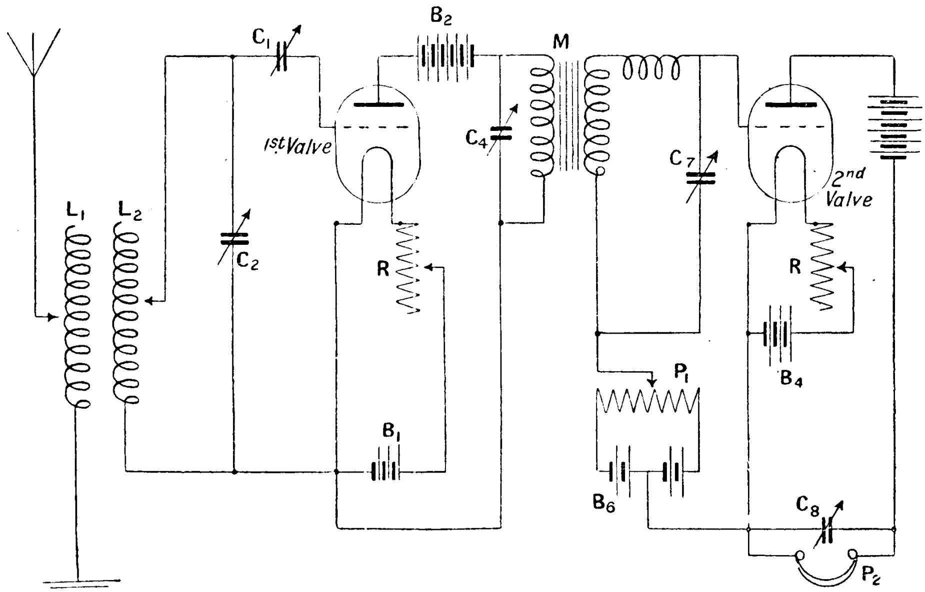
radio-frequency, no audible results would be obtained from the telephones if connected in the plate circuit of this valve.

Consider next the effect of a series of strong signals arriving. The grid potential now varies by considerably larger values, and, as will be seen by the shape of the valve characteristic curve, the positive half of the incoming wave will produce a much larger increase in the plate current than the decreased plate current due to the negative wave of the same signal. The net result is what amounts in effect to a rectified current, which would flow through the telephone P_3 if it were connected in the plate circuit of the first valve.

Should the incoming signal be too weak to give this unsymmetrical relaying effect in the plate circuit of the first valve, response can only be obtained in the receiving telephone by amplifying the plate oscillations of the first valve through the medium of a second or third valve. If the second valve is carefully adjusted to the proper operating characteristic, the amplified oscillations received and impressed upon its grid and filament will cause a rectified current to charge the telephone condenser C_8, which then discharges into the head telephone P_3 in one direction.

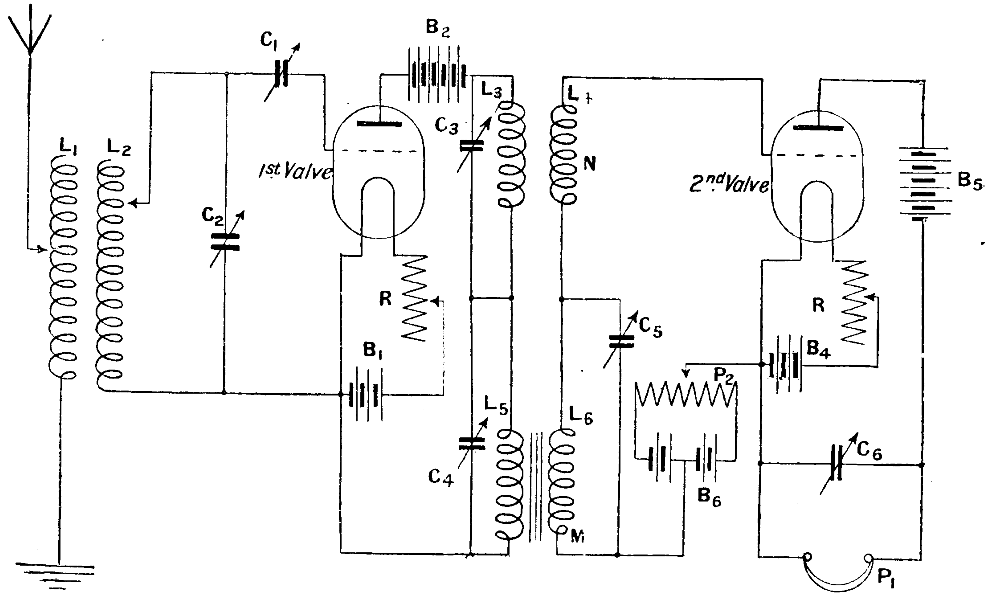
Rectified current obtained through the amplifying characteristic of the valve is only rectified in the sense of the positive impulses being of much greater magnitude than the negative impulses, which are relatively negligible by comparison. In adjusting the apparatus shown in Fig. 1, the potentiometer P_1 requires setting so that the grid potential will have some value along the straight part of the characteristic curve (Fig. 2) at or near the point B, for instance. The grid potential of the second valve is then adjusted by the potentiometer P_2 to a point round about A (Fig. 2), so that full advantage may be taken of the unsymmetrical conductivity of the valve. The condenser C_8 will then receive a unidirectional charge during each wave train, and its discharge through the telephone P_3 will be practically in one direction only.

There is also another way of arriving at the same results, which consists of inserting a grid condenser as shown at C_1, Fig. 1. The incoming waves are then rectified and a charge accumulates in the grid condenser during the period of the wave train. As the charge increases the plate current in the second valve decreases, and at the termination of the wave train



AUDIO-FREQUENCY CASCADE AMPLIFICATION

Fig. 3. Through the iron-core transformer M the plate circuit of the first valve and the grid circuit of the second valve are coupled inductively. For purposes of adjustment a battery and potentiometer are placed in the grid circuit of the second valve



COMBINED AUDIO- AND RADIO-FREQUENCY CASCADE AMPLIFICATION

Fig. 4. Connexions are shown in this diagram of the cascade arrangement combining audio- and radio-frequency amplification. A by-pass condenser is used for the radio-frequency current passing the audio-frequency inductance

the charge leaks out from the grid condenser through the valve or through a special leak resistance in shunt with it, allowing the plate current from battery B_5 to return to its normal strength.

This action is repeated with each wave train of the incoming signal. Audio-frequency cascade amplification is shown in diagram by Fig. 3, where the plate circuit of the first valve and the grid circuit of the second valve are coupled inductively through the iron-core transformer M.

The primary and secondary coils of M consist of several thousand turns of fine wire wound over an iron core common to both. Condensers C_4 and C_7 are provided for tuning the primary and secondary circuits of M to the desired audio-frequency of 300 to 1,000. In order to provide for maximum amplification the second valve has a battery B_6 and potentiometer P_1 included in its grid circuit for purposes of adjustment.

The way in which this circuit functions is as follows: Successive groups of incoming waves are converted to audio-frequency variations of plate current B_2 through the charge and discharge of the grid condenser. This component of the plate current is impressed upon the grid circuit of the second valve through the coupling transformer M. By means of the grid potentiometer P_1 the second valve is adjusted for the best amplification of the impressed audio-frequency current. The condenser C_1 in the first valve circuit may be dispensed with and the valve adjusted for unsymmetrical relaying if a special grid battery is provided as with the second valve.

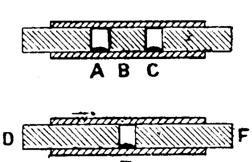
A simple circuit for audio-frequency amplification is also possible, consisting of three valves connected in cascade, these being coupled together through simple iron-cored transformers between the output and input circuit of successive valves.

As a final example of cascade connexion for combined audio- and radio-frequency amplification, Fig. 4 may be studied. By means of these connexions both the radio- and audio-frequency components of the plate or output circuit of one valve may be amplified simultaneously through a second valve. In this system the audio-frequency component of the plate circuit is impressed upon the grid circuit of the second valve through transformer M.

Condenser C_4 serves as a by-pass for the radio-frequency currents past the audio-frequency inductance L_5. Condenser C_1 is for the purpose of tuning the plate circuit to the incoming waves, that is the radio-frequency component of the plate current, while C_5 tunes the grid circuit of the second valve to the same frequency, the radio-frequency current of the plate circuit being impressed upon the grid circuit of the second valve through the coupling L_3 L_4. The action of condenser C_5 is to by-pass the radio-frequency current in the grid circuit of the second valve past the audio-frequency coil L_6. The potentiometer P_2, shunting battery B_6, enables the operator to obtain the best relaying characteristic of the second valve. If preferred, a grid condenser can be inserted in the circuit of the second valve and the relaying action obtained without the use of a potentiometer. It is desirable to shunt the battery B_6 by a condenser of fixed capacity.

CASED CORD. A thin rope, the exterior of which is covered with braided copper wire. It has some uses in wireless work, as, for example, the aerial. It could be used for the aerial wire, or for stay ropes, the wire covering acting as an efficient protection against chafing of the guy ropes.

CASTELLI COHERER. A form of self-restoring cymoscope, the invention of an Italian. It has been made in several forms, two being illustrated. In one application a glass tube, about 3 millimetres diameter, forms the exterior, and into this are fitted two electrodes made of iron or carbon. These electrodes are arranged so that they nearly meet in the middle of the tube, and in the space between them is placed a drop of mercury.



CASTELLI COHERER

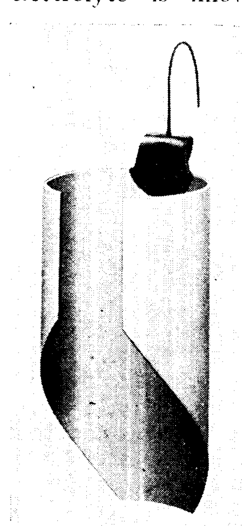
Fig. 1. (above). Between electrodes is a block of iron, B, and drops of mercury at A and C. Fig. 2. (below). At E is a drop of mercury, and D and F are carbon or iron electrodes

In an alternative arrangement a separate block of iron or carbon, B, Fig. 1, is placed between the electrodes, and drops of mercury are placed between the three, as at A and C, in Fig. 1. When the electrodes are correctly adjusted and a circuit arranged with a single cell, a telephone and a resistance, and an electric wave falls on the tube, it causes a sudden decrease in the resistance between the electrodes, and a sharp click is heard in the telephones. The tube, however, immediately returns to its original high resistance, and if the waves continue the sound in the telephone is nearly continuous.

In a modification, as shown in Fig. 2, the electrodes, D, F, are composed of carbon or iron; one is fixed and the other electrode adjustable. The space between is occupied by a drop of mercury, E. It functions in a similar manner to that in Fig. 1, and is sometimes known as the Italian navy coherer.

CATENARY CURVE. The curve assumed by a rope suspended freely between two supports. For example, the wire of an aerial when at rest is of this character.

CATHODE. In a cell the electrode by means of which the current leaves the electrolyte is known as the cathode. The cathode is also known as the negative electrode, and is indicated in diagrams by the sign −.



ZINC CATHODE

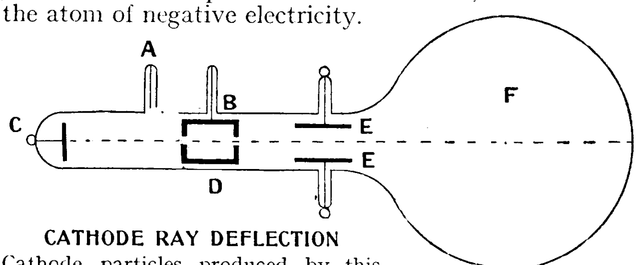
The zinc or negative plate of a Daniell primary cell

Courtesy Siemens Bros. & Co., Ltd.

In a Geissler tube, a simple cylindrical glass tube fitted with a pair of plane parallel electrodes, the cathode is that electrode next Crookes' dark space, followed by the negative or cathode glow. From the cathode are given off the well-known cathode rays.

Various materials are used for the cathode in arc oscillation generators. Poulsen, Dubilier and others use a carbon cathode as being the most suitable for the production of continuous high-frequency oscillations for wireless purposes. The cathode is usually rotated by clockwork or other mechanism to ensure a fresh surface of carbon being continually presented to the arc. Both the anode and the cathode in Ruhmer's arc consist of a moving aluminium wire. In Moretti's arc both electrodes are of copper, and in the T.Y.K. arc magnetite is generally used for the cathode. The figure shows the zinc cathode of a Daniell cell. *See* Anode; Anion; Arc; Cation; Electrode.

CATHODE RAYS. Particles projected from the cathode or negative electrode of a high vacuum tube. If a glass tube is exhausted of gas, two electrodes are sealed through the glass, and an electric current passed through, particles of some kind are projected from the cathode. The anode and cathode are generally made of platinum. The discovery of the cathode rays is due to Crookes, and Sir Joseph Thomson showed, in 1899, that the cathode particles were independent of the nature of the cathode or the rarefied gas in the tube, a fact which led to the discovery that the cathode particles were electrons, the atom of negative electricity.



CATHODE RAY DEFLECTION

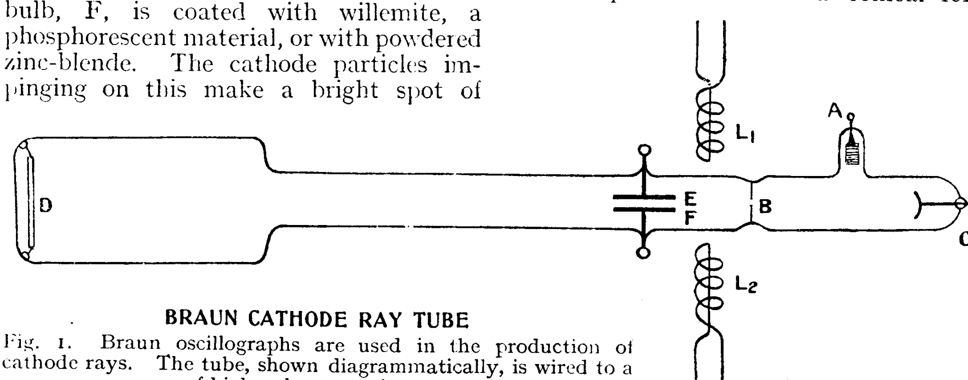
Cathode particles produced by this tube are limited to the narrow path shown by the dotted line and can be deflected by electric or magnetic deflection at E E

The figure shows the method by which the cathode rays are produced. C is the cathode, A the anode placed in a side tube of the main glass tube so as to avoid interference with the cathode rays. B, D are two metal baffle plates, pierced by a narrow slit. Their purpose is to limit the cathode rays to a narrow path. E, E are two metal plates, parallel to one another, which can be charged to a difference of potential by a battery. E, E are placed between the poles of a powerful magnet to deflect the rays. The inside of the bulb, F, is coated with willemite, a phosphorescent material, or with powdered zinc-blende. The cathode particles impinging on this make a bright spot of light, and from the amount of deflection the ratio of the electric charge on each particle to its mass, or e/m, may be calculated. *See* Electron.

CATHODE RAY TUBE. Highly exhausted tube used in the production of cathode rays. The tube is illustrated in the previous article. Fig. 1 shows another form, the Braun cathode ray tube, or oscillograph. C is the cathode, A the anode, and B a baffle screen pierced to allow a thin stream of rays to pass through from the cathode. D is a fluorescent screen placed at the other end of the tube, E and F parallel metal plates for deflecting the rays. L_1, L_2 are magnetic coils placed close to the deflecting plates to deflect the cathode stream magnetically. The anode of the tube is connected to the positive terminal and the cathode to the negative terminal of a source of high voltage continuous current of several thousand volts. When the tube is set in operation a brilliant spot of light appears in the fluorescent screen, and the ray, being deflected up and down by the alternating magnetic field of the coils, the spot of light is expanded into a line of light. The stream of electrons is increased as the voltage across the terminals is increased.

Fig. 2 shows a modification of the Braun cathode ray tube as developed by the Western Electric Company. The instrument can be used for frequencies approaching one million per second.

The tube consists of a glass three-electrode tube, about 30 cm. long, in the form of a cylinder about 4 cm. diameter, which spreads out into a conical form

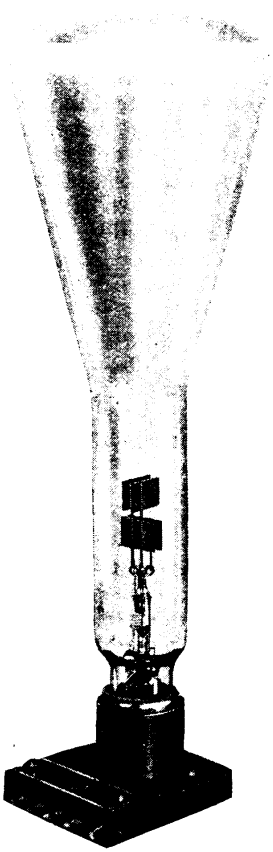


BRAUN CATHODE RAY TUBE

Fig. 1. Braun oscillographs are used in the production of cathode rays. The tube, shown diagrammatically, is wired to a source of high-voltage continuous current

with a slightly rounded end. The diameter of the large end is about 10 cm.

The cathode consists of a filament coated with active oxides, and supplies the requisite number of electrons for the rays at a dull red heat. The anode is a small platinum tube set about 1 mm. from the filament, which is bent into the form of a nearly complete circle. Between the filament and the anode is a small circular screen with a hole in the centre just smaller than the circular filament.



CATHODE RAY OSCILLOGRAPH

Fig. 2. The photograph shows a modification of the Braun cathode ray tube, as made by the Western Electric Company

A battery of 250-400 volts is connected between the anode and the cathode. This battery raises the anode to a positive potential with respect to the filament, and the electrons, which are supplied by the hot filament, are accelerated by the electric field so produced. A small fraction of the electrons pass completely through the tubular anode and constitute the cathode rays.

These rays pass between two pairs of deflecting plates set at right angles to each other, and fall upon the large end of the glass tube, which is covered with a fluorescent mixture to render them visible. If the two plates of either pair of deflecting plates are not at the same potential, the rays will be deflected in a plane perpendicular to the plates by an amount proportioned to the difference of potential.

If an alternating difference of potential be applied, the spot on the screen is drawn out into a line. The rays can also be deflected if a pair of parallel coils be mounted outside the tube and a current passed through them in series. The deflection is proportional to the current.

The following are some of the applications of the cathode ray tube :—

(1) Examination of wave forms of all types of generators. (2) Examination of wave forms of rectifiers. (3) Examination of phenomena in arcs and sparks. (4) Examination of thermionic valve characteristics and phenomena occurring inside valves. (5) Characteristics of X-ray and other discharge tubes. (6) Examination of phenomena at radio-frequencies, including modulation, etc., in radio telephony and telegraphy. (7) Measurement of hysteresis and dielectric loss in materials. (8) Examination of the phenomena in explosions with the aid of the Piezo electric crystal. (9) Study of induction coils. *See* Cymoscope.

CATION. Term used in electrolysis to denote the constituent of the electrolyte which migrates towards the cathode. The earliest systematic study of electrolysis was made by Faraday, who suggested the terms anode, cathode, anion, and cation.

Suppose the two electrodes are two strips of platinum and the electrolyte slightly acidulated water. Then when a current passes oxygen is liberated at the surface of the anode, and hydrogen at the surface of the cathode. The two gases are liberated simultaneously at the anode and the cathode, but the oxygen in the liquid travels to the anode, and the hydrogen travels to the cathode, so that only one gas is given off at each electrode. The cation is the gas which travels with the electric current, *i.e.* towards the cathode, in this case hydrogen. *See* Anion ; Electrode.

CAT LADDER. A construction generally in the form of two parallel ropes with wooden rounds between them, thus forming a species of ladder. It is chiefly found in wireless work as the method for ascending the interior of a box lattice or other tall mast. When such a ladder is provided, it ought to be more than amply strong, as, being exposed to the weather, it is peculiarly liable to early depreciation. Others made of steel or iron, if galvanized or otherwise protected against rusting, are stronger and far more durable. In the case of a light wooden mast, the ladder could be incorporated into the structure itself. The mast should be designed with due regard to the weight of anyone working at the top of the ladder, for a load of, say, some 11 stones is a serious consideration that ought to be specially provided for, especially in the case of the smaller amateur-made masts.

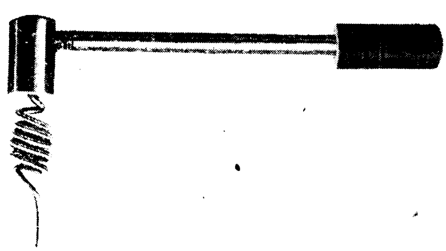
CAT'S-WHISKER. Name given to the fine wire that effects contact between the aerial and the crystal in a crystal detector. The cat's-whisker plays an important part in the crystal detector, for it is the actual contact medium between the incoming

SPRING CONTACTS FOR CRYSTALS

Fig. 1. Crystal detectors using wire contacts may employ any one of these "cat's-whiskers." Top left is a standard spring coil, right, a single coil, and bottom, tapered ribbon. The last is used when pressure is required

current and the crystal, and is the point at which it is generally assumed that rectification takes place.

Cat's-whiskers are not always used on a crystal, nor do all crystals function with one, but silicon, galena, hertzite, radiocite, and other very sensitive crystals generally have this form of contact. The cat's-whisker is a fine wire, terminating in a point, and usually coiled into a small spring a short distance from it. The other end is attached to a holder with an ebonite



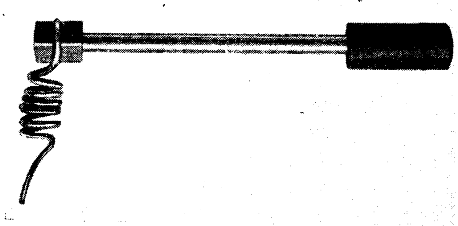
CAT'S-WHISKER ATTACHMENT

Fig. 2. Methods of holding the cat's whisker vary. Here is a screwed contact arm with an ebonite end piece for insulating the fingers when adjusting. The cat's-whisker is a simple spiral spring

handle. The arm thus formed is adjustably mounted in a suitable support, so that the whisker can be moved over the whole area of the crystal.

Some standard cat's-whiskers are shown in Fig. 1. On the top, left, is a straight coil for the horizontal type of detector, on the right is the single-turn type, and at the bottom a strong pattern for silicon and other fairly stable crystals that require a considerable pressure to maintain contact. One convenient method of attaching the whisker to the arm is illustrated in Fig. 2, and shows the arm screwed into the upper side of a small cap of brass. The arm is screwed into this far enough for it to intrude into the hole drilled up through the centre of the cap. The whisker is placed into this hole and the arm tightened, thus holding the wire firmly in place. A sound contact at this point is of great importance, as the quantity of current that passes from the aerial through the crystal is very small.

Alternatively the method shown in Fig. 3 can be followed, and consists of gripping the whisker between two nuts screwed to the end of the arm.



NUT GRIP CAT'S-WHISKER HOLDER

Fig. 3. Two nuts screwed to the end of a contact arm in this manner make a simple means of gripping a cat's-whisker

Another type of whisker takes the form of a bundle of wires attached to an arm similar to the foregoing. Others are made from a thin piece of foil cut into a series of points and then rolled up to make a brush. The idea with both these patterns is that there are more points to make contact and therefore a better result will be obtained. With most crystals, however, there seems to always be one point that brings in the signals better than any other, and a fine thin cat's-whisker with a sharp point gives the best results. The greatest objection is the difficulty of searching for the most sensitive spot.

A method of overcoming this which has been advocated consists of the use of a cap that fits over the crystal cup and has fitted at the top a fine wire gauze. The end of the whisker passes through any one of the holes in the gauze, which then keeps the whisker in place. Another form of cat's-whisker is made by flattening the end of the wire and cutting it to a spear-headed shape and filing the points perfectly sharp.

The material of which the whisker should be made ought to be suited to the particular crystal in use and to the nature of the circuit. For example, a hertzite crystal and a very fine brass wire whisker filed to a needle point give excellent results. With copper pyrites crystals, a whisker of gold or phosphor-bronze gives good results. With silicon the whisker may be of steel or copper. The reason for this use of different materials is somewhat obscure, but is probably due to the thermo-electric couple that is thereby formed when the aerial current is passing. The adjustment of the whisker is all-important, but often the loudest signals are only obtainable with such a delicate adjustment that a chance blow on the table will upset the balance and the reception will be ruined until the whisker has again been adjusted.

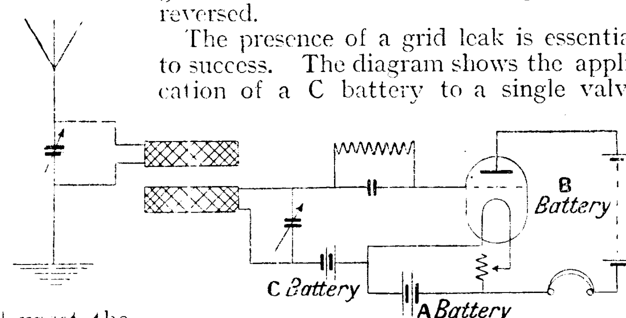
When exploring a crystal in search of sensitive spots, as soon as a passable spot has been found it is as well to work around that region carefully, slightly tapping the end of the arm rather than actually moving it, as the slightest variation of pressure or angle will generally make all the difference. The sharp point of the whisker has to be adjusted to the facet on the crystal, and to do this needs but the very slightest movement, which is more easily imparted in this way than by a more decided effort.

After a whisker has been in use for some time the point may become blunt or covered with a film of oxide, either of which will impair the reception; the remedy is to file the point with a very smooth file or with fine emery paper, stroking it in the direction of the wire so as to resharpen it as well as clean the surface. Improvements are sometimes possible with variations in the pressure exerted by the spring, but this is purely a matter for individual experiment, as a delicate sense of touch has a great bearing on the successful manipulation of the modern super-sensitive crystal.

Extemporized whiskers are made in numerous ways, from a pin stuck through a cork, to a point filed on the end of the copper wire connecting to the telephones. *See* Crystal.

C BATTERY. The third battery in a circuit, generally used as a grid-biassing battery. It may take the form of a dry cell or cells or a small accumulator, and in one common application is wired into the grid-filament circuit. Properly applied it has the effect of increasing signal strength. The usual procedure is to wire the positive side of the C battery to the filament and the negative to the grid, but on some circuits the polarity is reversed.

The presence of a grid leak is essential to success. The diagram shows the application of a C battery to a single valve



POSITION OF A "C" BATTERY

Three batteries are used in circuits such as that illustrated to give a biassing potential to the grid, thereby increasing signal strength

receiver, and in this case the aerial tuning is effected with a plug-in or basket coil and a small variable condenser. The grid circuit contains the secondary coil and the C battery, also a variable condenser across the terminals of the coil to provide for the tuning of this circuit. The remainder of the circuit follows standard practice. *See* A Battery; Accumulator; B Battery; Circuit.

C.C. This is the standard abbreviation for cubic centimetre. *See* C.G.S.

CELL. Expression used in electricity to designate the unit of a voltaic battery. In its most common form it comprises a jar containing a liquid called the electrolyte, and the two elements or electrodes immersed in it. An electro-chemical action is set up thereby, with the result that a current of electricity can flow around a circuit when the terminations of the elements are joined to either end of the circuit.

There are many forms of cell, and all of them have a distinguishing name, under which headings they are described in this Encyclopedia. For example, the commonly used Leclanché cell comprises an outer glass jar, the elements are respectively carbon and zinc, and the electrolyte a solution of sal-ammoniac.

The standard cell is known as the Clark cell; others that are in fairly extensive use are the Daniell and Grove. Several forms of dry cell are dealt with under that heading. They are distinguished by the fact that the electrolyte is in the form of a paste.

There are two great classes of cell used in wireless work. The first are the primary cells, which are characterized by the fact that they function as a self-contained unit, as the internal action in the cell itself generates the electricity. The second class are the secondary cells or storage batteries, and these depend upon a preliminary electric charging for their action. The secondary cell cannot yield a practicable current except after an electric charge has been imparted to it by the passage of an electric current. This changes the electro-chemical nature of the cell, and the effort it puts out to restore itself to the pre-charged state accounts for the output of electrical energy. *See* Accumulator; Battery; and under the names of the various cells.

CELLULOID. A manufactured article composed of pyroxylin or guncotton, with camphor and other substances.

The material is made under pressure, and is obtainable in the form of sheets, rod, and tube. When polished it is nearly as transparent as glass, but varieties are obtainable that are coloured in manufacture, others are white and opaque. The material is highly inflammable, and the greatest possible care must always be taken to avoid any chance of a naked light coming into contact with it.

Applications in wireless work of celluloid include the cases for small portable accumulators, cases for variable condensers, dials, valve windows, and as a dielectric for condensers. Other applications are as set squares and curves used for plotting the characteristic curves of valves and other drawings.

Celluloid is a good insulator when cold, and at a temperature of 68° F. has a puncturing resistance varying from 12,000 to 28,000 volts on samples 0·01 in. thick, but the same sample at 212° F. has its resistance reduced to 3,000 to 9,000 volts. The experimenter uses celluloid for various purposes, but all the processes involved resolve into a few simple methods.

For example, celluloid in the form of rod is turned in a lathe in the same way as ebonite. The work should run at as high a speed as the material will stand without tearing. But the item of paramount importance is to guard against overheating. This is one of the causes of a rough surface; but in view of the highly inflammable nature of the celluloid it is most necessary to guard against fire. Only very light cuts should be taken, and the tools kept very keen, the edges being sharpened regularly on an oilstone.

Be very careful of the turnings, as they are easily ignited if a cigarette end falls upon them. If they are kept clean and stored in a dry place, they are very handy for the making up of a cement by dissolving in amyl-acetate or acetone (*q.v.*). There are several brands of fireproof celluloid on the market, and these are preferable to the other kind, as the fire risk is greatly reduced.

In wireless work celluloid is mostly used in the form of sheets, generally of the transparent variety. This is obtainable in sheets about 24 in. wide and in many thicknesses, generally distinguished by a number corresponding to the number of thousandths of an inch that the sheet is thick. For many types of fixed condenser, celluloid can be used, and old photographic films with the emulsion cleaned off are quite suitable and inexpensive. The film is simply cut to shape with scissors and applied as requisite.

How Thick Sheets are Cut

When a stouter sheet has to be cut, as, for instance, in the preparation of a case for a variable air condenser, the first step is to mark the width of the piece on the sheet, doing this with the point of a pin guided with a ruler. Then with a sharp pocket knife make a deep scratch along the sheet, using a straight batten as a guide, in the manner illustrated in Fig. 1. Rest the sheet on the edge of the table so that the cut comes over the edge, and bend the sheet over with the right hand while holding down the other part of the sheet with the left, as shown in Fig. 3, when the sheet will break neatly along the incised line.

The strip is then cut to the desired length and rolled around as in Fig. 2, the ends joined with cement or rivets of the bifurcated variety, or by the use of brass, flat-headed rivets. The heads of the latter can be closed in the manner illustrated in Fig. 5 by placing the rivets through the holes drilled in the sheet,

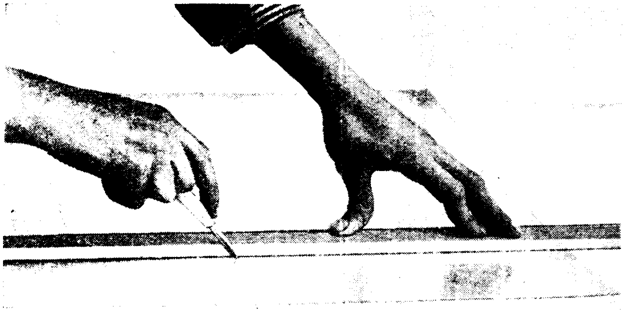


Fig. 1. Celluloid is obtainable in sheets, as the one here being cut. Marking out may be done with a pin or sharp point, and cutting partially accomplished with a penknife

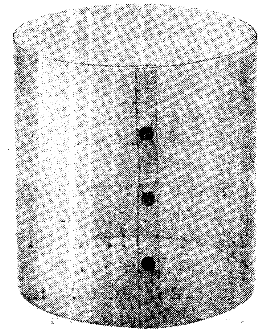


Fig. 2. Variable air condenser case. This is made by rolling a celluloid strip and fastening with bifurcated rivets

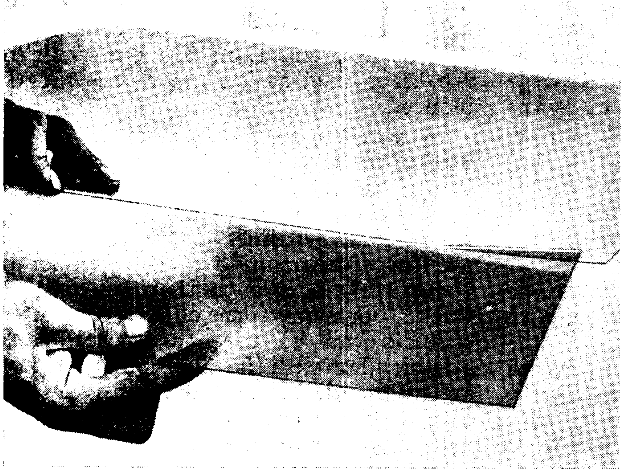


Fig. 3. Sheet celluloid, having been partly cut through, is broken off in this manner. The part to be severed is held over the edge of a table or bench

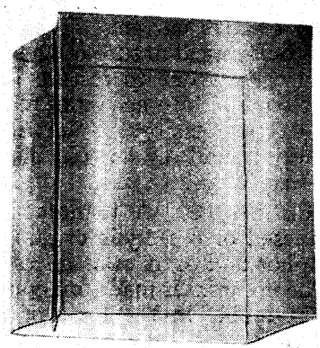


Fig. 4. Accumulator cases are common examples of the use of celluloid. This is a case in an early stage of construction

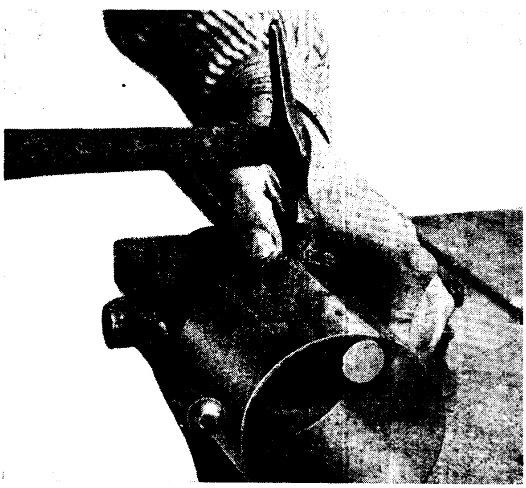


Fig. 5. Riveting is carried out in this way by hammering, while the celluloid is supported by a wooden rod held in a vice

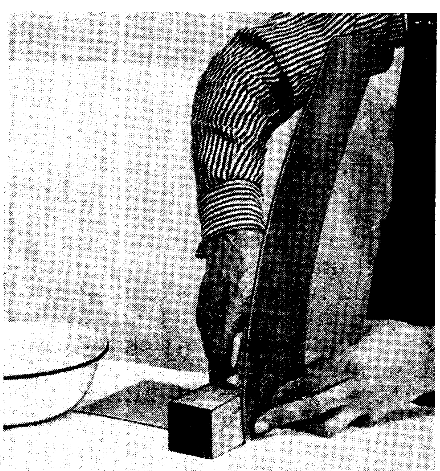


Fig. 6. An angle bend is being made in a sheet of celluloid. It is immersed in hot water to make it pliable

Fig. 7. Cement has been applied to the joint and a weight is being held down over it to prevent buckling until the cement sets

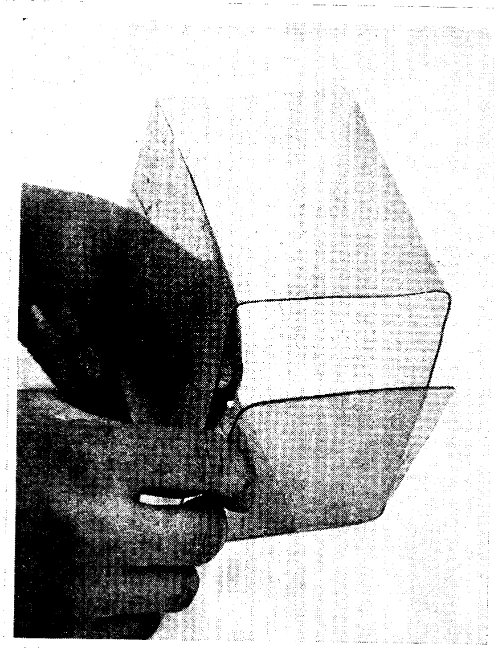


Fig. 8. Before the bottom of the case is fixed it must be tested, as here shown, by fitting loosely and making any necessary adjustment in size

Fig. 9. Strips of celluloid are made into angle pieces by soaking in hot water, inserting in a slit in a block of wood, and pressing over as illustrated

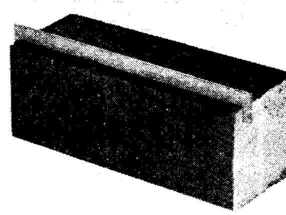


Fig. 10. Here is the celluloid strip before it is prised over to make an angle piece

Fig. 11. Angle strips are finished off by filing the edges true and even

Fig. 12. Corners of an accumulator case are fitted with angle pieces in this way. The case is blocked up with wood to facilitate cementing

MAKING A CELLULOID ACCUMULATOR CASE

resting the heads on a wooden rod held in the vice, and, after placing a washer over the rivet, closing it by light, sharp blows with a light-weight riveting hammer.

In the absence of a wooden rod, a bar of iron will answer all requirements. As another example of the use of sheet celluloid, consider the construction of a case for an accumulator. In this case a strip will be needed long enough for all the four sides, plus an extra ½ in. or so for the overlap of the joint.

Having cut such a strip, mark it out so that the join will come in the centre of the end; and provide a block of wood, planed up square on all faces and a little longer than the height of the case. A supply of boiling water is needed, also a basin of sufficient size to allow the sheet to be immersed.

Making an Accumulator Case

To bend the sheet, it has to be immersed in the boiling water until it softens, when it is immediately removed and placed on the bench on a piece of clean paper. The wood block is rested on it with one edge on the line where the bend is to come. Lift up the outer part of the sheet and, with the fingers, work the sheet up to the block and press it home, as shown in Fig. 6.

All the four corners are bent in the same way, when the work will appear as shown in Fig. 7, ready for the joining process.

Prior to joining the case, make sure it is square and will stand upright on the bench. Should it not do so, reheat the corners and straighten it up. The joint is made with celluloid cement or with amyl-acetate applied with a brush liberally to the joint surfaces. A second coat is applied immediately the first is tacky, and the faces quickly brought into contact, pressed together, and secured with a heavy weight.

This stage is illustrated in Fig. 7. The next item is to fit a bottom to the case. This is shown in Fig. 8, where the sheet is being offered into place as a test. Before it can be fixed, a supply of angle strips will be needed. They are prepared by making a block of wood and cutting a groove in it near the edge. Insert a narrow strip of celluloid into it, so that one half the strip is in the groove and the other projects above it, as shown in Fig. 10.

The strip is then removed from the block and thoroughly boiled, taken from the water, slipped into the groove, and then the block turned over so that the projecting strip is doubled under, as shown in Fig. 9. The strips are finished by putting the angle strip into the block again and then filing across the projecting portions, as shown in Fig. 11.

Having prepared the angle pieces and cut them to lengths so that they will fit into place, the case is blocked up with wood and supported at the corners with cross-pieces tied together with bell wire or thin cord in the manner shown in Fig. 12, where the location of the wood blocks a little below the top of the work is clearly visible. The top sheet is then placed in position and rests on the top of the wood blocks as shown, and one of the angle pieces coated with cement or amyl-acetate or acetone and pressed into contact with the edge of the case. It can be held with paper clips or in any other convenient manner.

All the angles are fitted in this way to the four sides, the case lifted sufficiently to allow the cement to flow under at the edges and then pressed home on the angles. This is accomplished by pressing the case bodily down on to the bottom sheet and then pressing the angles into contact and weighting them until they have set. The work should then be tested to ascertain that it is watertight and any defects made good with cement. The top of the case is fitted in the same way, with the addition of the collars and fittings for the accumulator lugs or terminals.

Should it be desired to mould the sheet to a curved shape, it can often be done by bending it in the hands while the sheet is warm, but more intricate shapes are obtained by pressing into a mould, and boiling or otherwise sufficiently heating the sheet. It will be appreciated that celluloid must never be heated over the fire, but always in water or in such a device as a fish kettle.

Liquid celluloid obtained by dissolving celluloid scrap in acetone or amyl-acetate to the consistency of a thin cream forms an admirable insulation varnish. The same mixture can be used to impregnate cardboard tubes for inductance formers, and to insulate exposed metal parts. When very diluted it makes a colourless lacquer for metal or wood.

Strips of linen or canvas, if immersed in the same mixture and wrapped around a wooden former and allowed to dry, the former removed, and the tube thus made coated several times in succession with the celluloid varnish, make a good insulation material for formers for the winding of numerous coils. *See* Acetone; Amyl-Acetate.

CENTI. This is the abbreviation used for one-hundredth. A centigrade thermometer, for example, has a hundred degrees or divisions between the freezing and boiling points of water. A centimetre is the hundredth part of a metre, and so on. *See* C.G.S.

CENTRE PUNCH. A hand tool used to make conical indentations in a piece of work to indicate the location of the centre of an intended hole.

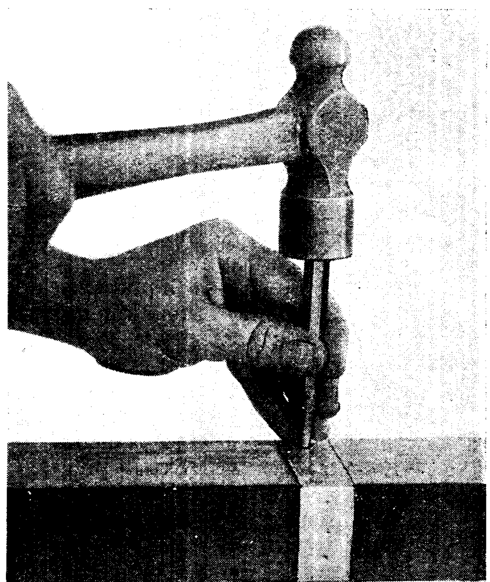
One of the most necessary tools for the amateur and professional worker, it is also one of the easiest to use. All that has to be done is to hold the tool in an upright position with the point pressed on the work exactly on the centre, and then strike the top of the punch with a hammer. This makes a shallow depression in the work known as a centre pop, and is the starting point for the drill used to make the hole. Centre punches are made from hard steel with knurled, hexagonal or octagonal grips, the top slightly rounded and the bottom pointed. The lower part tapers considerably.

Automatic centre punches have an enclosed spring-pressed hammer which strikes a blow automatically when the punch is depressed. They are most convenient and accurate in use. Bell centre punches have an outer portion in the shape of a funnel, and are used by placing over the end of a shaft or circular object and striking the punch in the usual way. Another type, known as the spacer punch, has a guide or pilot punch that is used to locate the position of the second hole by setting it in the first. It is in this respect a combination of divider and centre punch that saves immense time when a long row of uniformly spaced centres have to be popped.

Apart from its legitimate application, a centre punch is useful for fixing thin metal plates to wood or other resilient material; all that has to be done is to pop a series of centres and the metal will be pressed into a conical pip with the point in the wood, thus holding it securely. Nuts may be secured to a bolt by making a centre pop at the junction of the nut with the bolt.

CENTRIFUGAL FORCE. Force exerted by a revolving body as a reaction on its fixed centre. If a weight is fastened to a string, for example, and then revolved in a circle, a force is exerted on the string by the body, increasing with the speed of the body in its circular path. This force is centrifugal force. The force varies as the square of the velocity, directly as the weight of the revolving body, and inversely as the radius of the path the body is describing.

CERUSITE. Whitish-grey lead ore, a carbonate of lead. It has been used as a crystal rectifier, but is much less effective than galena for the purpose. *See* Galena.



FIXING A STRIP BY PUNCHING

Popping a number of punch indents in this way forms a means of attaching a metal plate to a wooden post or bar

C.G.S. This is the usual abbreviation for the centimetre-gramme-second system of units. The system is also known as the absolute system of measurement, and is the one most widely used in scientific measurements. Its use is also extending rapidly in all branches of engineering.

The C.G.S. system is most convenient for measurement and calculation in that it is a purely decimal system. The centimetre is the unit of length, the gramme the unit of mass or weight, and the second the unit of time, in the system. From these units are derived all the other units.

In the absolute system the unit of velocity is one centimetre in one second, and acceleration due to gravity, measured at Paris, is 981 centimetres per sec. The unit of force is one dyne = 1/981 of the weight of a gramme at Paris. It is more closely defined as that force which, acting on one gramme for one second, produces a velocity of one centimetre per second. The unit of work is one erg, or one dyne-centimetre, and the unit of power 10^7 ergs per second = 1 watt. In practice the erg is too small, and the unit adopted is the joule = 10^7 ergs, so that the unit of power is one joule per second. The kilowatt is another practical unit often used. The kilowatt-hour is a Board of Trade unit and is often known as the kelvin.

In the C.G.S. system all multiples and sub-multiples are expressed by Greek and Latin prefixes respectively. Thus mega = 10^6 times; kilo, 10^3 times; hecto, 10^2 times; deka, 10 times; deci, 10^{-1} times, or a tenth; centi, 10^{-2} times, or a hundredth; milli, 10^{-3} times, or a thousandth; and micro, 10^{-6} times, or a millionth.

The C.G.S. standard of liquid measure is the litre, the volume of one kilogramme of pure water at 4° centigrade.

The following are the chief approximate relations between the C.G.S. system and the British system of units:—

1 metre	=	39·37 inches
1 kilometre	=	0·6214 mile
1 mile	=	1·609 kilometres
1 kilogramme	=	2·2046 lb.
1 pound weight	=	$4·45 \times 10^5$ dynes
1 foot-pound	=	1·356 joules
1 horse-power	=	746 watts

Electric Units. The systems of units for electric and magnetic quantities are based upon the C.G.S. system. Actually there are three systems of measurement, two theoretical and one practical. The two first are based on definitions of the unit quantity of electricity and of the unit magnetic pole, and the last on units derived from the magnetic system.

The unit quantity of electricity is defined as that quantity which if placed on a small sphere in air will repel an equal quantity of the same sign on a sphere placed one centimetre away (measured between centres) with a force of one dyne. This unit is known as the electrostatic unit. If the spheres are not in air the force of the attraction between them depends on the dielectric constant of the material separating them. The force in dynes is Q^2/kd^2 where k is the dielectric constant, Q the quantity of electricity upon each sphere, d the distance between their centres measured in centimetres.

The electrostatic unit of potential at a point is measured by the work done in bringing up a unit of electricity to that point from an infinite distance. It is equal to about 300 volts.

The electrostatic unit of current is a current which conveys one unit of quantity of electricity per second across any section of a conductor. It is about 0·000333 micro-ampere.

The unit of capacity of a conductor is measured by the quantity of electricity required to charge it to unit potential when it is infinitely removed from all other conductors. It is measured in terms of a length in the electrostatic system as so many centimetres, if the dielectric is air.

The resistance of a conductor is measured by the quotient of the potential difference between its end and the current flowing through it, assuming there are no internal sources of electro-motive force.

System of Electro-magnetic Units

In the electro-magnetic system of units a unit magnetic pole is defined when two long thin magnets, with opposite poles placed one centimetre apart in air, attract each other with a force of one dyne. In this system a unit current is a current such that if flowing in a circular arc of one centimetre radius each unit of length of it will act on a unit magnetic pole at the centre with a force of one dyne. The unit of quantity is the quantity of electricity conveyed by the unit of current in one second, and equals 10 coulombs. The electro-magnetic unit of potential is defined, like the electrostatic unit, as the work done in bringing up one electro-magnetic unit of quantity from an infinite distance, and is $1/10^8$ volts. The unit of capacity is 10^9 farads, which equals 10^{15} microfarads.

The electrostatic and electro-magnetic units are either too small or too large for ordinary use, and the third system of electrical units is the practical one. The table below gives these units in the C.G.S. system.

Name of Quantity	Name of Unit.	Equivalent in E.S. Units.	Equivalent in E.M. Units.
Current ..	Ampere	3×10^9	1/10
Quantity ..	Coulomb	3×10^9	1/10
Potential ..	Volt. ..	1/300	10^8
Resistance	Ohm ..	$1/(9 \times 10^{11})$	10^9
Capacity ..	Farad ..	9×10^{11}	$1/10^9$

The farad is too large for use in wireless calculations, and the microfarad is the more usual unit of capacity.

The practical measurements of these units were defined by an Electrical Congress held in London in October 1908. In addition, certain other units have been adopted, such as the henry, the unit of inductance. *See* under the names of the various units. *See also* International Units; Units.

CHAFFEE, E. L. American wireless expert. Born April 15th, 1885, at Somerville, Massachusetts, United States of America, he was educated at the High School, Somerville, and the Massachusetts Institute of Technology in Boston, where he took his degree in electrical engineering. Graduating in physics at Harvard University, he became lecturer in radio-telegraphy there, and afterwards engaged in research and consultation work in radio-telegraphy.

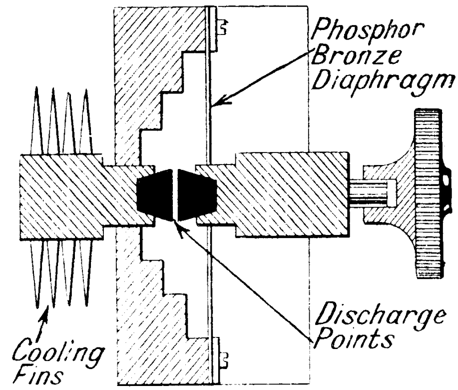
Chaffee is fellow of a number of American scientific societies and has written largely on wireless subjects, including "New Method of Impact Excitation of Electric Oscillations and their Analysis by the Braun Tube Oscillograph," "Regeneration of Coupled Circuits," etc.

In 1911, Chaffee developed his quenched spark gap system between electrodes of copper and aluminium, for small power transmission.

CHAFFEE SPARK SYSTEM. This system was developed by Dr. E. L. Chaffee for small power transmission up to ranges of about 100 miles. The electrodes of the spark gap are formed of copper and aluminium, and the sparking surfaces have an area of 0·2 and 0·4 square inch respectively, while the length of the spark gap itself can be varied between the limits 0·04 to 0·09 millimetre.

The gap is shown in section in Fig. 1. On the left of the figure an electrode is mounted in a holder having heat-radiating fins and is fixed in a gas-tight casing. The electrode on the right has a similar holder and is also provided with cooling fins, but passes through a phosphor-bronze diaphragm clamped against a rubber washer to seal the gas chamber effectively. This chamber can be filled either with hydrogen gas or with alcohol vapour when at work.

Variations in type of this gap are found, particularly in larger-powered apparatus. Sometimes an aluminium disk electrode is rotated rapidly in front of a stationary copper plate. A feature of the Chaffee spark system is that the spark frequency must be a whole number sub-multiple of the oscillation frequency, that is to say, the spark frequency must be exactly one-half, one-third, one-fourth, etc., of the oscillation frequency to ensure that the



GENERAL ARRANGEMENT OF SPARK GAP

Fig. 1. Two electrodes are here seen spaced. On the left the electrode is mounted in a holder having radiating fins. The right-hand electrode passes through a diaphragm clamped against rubber washers to seal the gas chamber

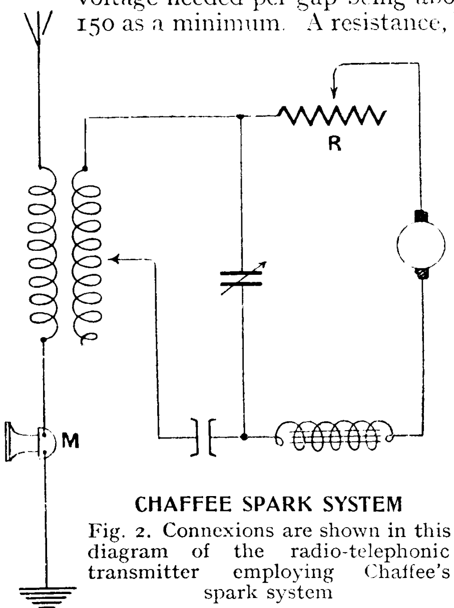
spark will always strike up in phase with the oscillations and prevent any hissing sound occurring in the receiver arising from "interference" or beat, which would be the case were the spark not properly timed.

Synchronizing the frequency of the spark in this manner is sometimes spoken of as the inverse charge frequency effect. The actual sparking rate depends upon the capacity effect in the closed oscillating circuit, and also on the strength of the supply current. It is therefore under control of any adjustments made to the latter, besides being sensitive to a fine setting of the gap length in the gas chamber. The frequency of sparking is very high with this device, and the spark is also highly quenched, so that it practically consists of only one half-cycle or loop of discharge current, in other words it is practically rectified. Probably the formation of a high-resistance film of oxide on the surface of the aluminium electrode plays its own part in this respect.

The oscillations in the aerial help to restart the spark again by their inductive effects in the closed circuit condenser;

this also keeps the spark in properly synchronizing sub-multiples with the oscillating frequency. When the spark frequency happens to be one-half or one-third of the oscillation frequency, the waves are practically undamped and give a pure continuous wave note when heterodyned at the receiver.

For radio-telephonic transmission the connexions are shown in Fig. 2. Two gaps may be used in series on 500 volts, or four gaps in series on 1,000 volts, the voltage needed per gap being about 150 as a minimum. A resistance, R,



CHAFFEE SPARK SYSTEM

Fig. 2. Connexions are shown in this diagram of the radio-telephonic transmitter employing Chaffee's spark system

must be provided with a fine adjustment, since the spark frequency depends largely on the strength of the supply current. The radiated energy may amount to 50 watts per gap, with an input of 150 to 400 watts per gap. The design of the microphone, M, in Fig. 2, will depend on the strength of the aerial current. For two gaps in series on 500 volts this will be about $1\frac{1}{2}$ amperes, and an ordinary low-resistance microphone might be used.

CHALCOPYRITES. One of the ores of copper used as a crystal rectifier. It is a copper-iron sulphide with a brilliant yellow colour, and is one of the most robust of the crystal rectifiers. The crystal is used as a low-potential rectifier in conjunction with zincite and tellurium. The well-known perikon detector is a combination of zincite and chalcopyrite. It forms a stable crystal combination and is not very liable to disturbance either by vibration or atmospherics. The combination has its point of maximum sensitiveness near the point of zero boosting voltage, that is to say, only a very small voltage is required. The perikon detector will work well without a battery, in fact. *See* Perikon.

CHAMFERING. A chamfer or bevel is an inclined face worked on the edge of a piece of material. In wireless work it is chiefly found on the edges of panels and dials, and around the woodwork of cabinets as a decorative finish.

The expert woodworker uses a regulad chamfer plane when making a chamferer edge, but the experimenter who does not do a great amount of woodwork can produce good results by correct manipulation of a chisel and plane. The method that may be adopted on wooden structures is shown in Fig, 1, where the way to work the edge with a chisel is clearly visible. For all this class of work it is imperative that the tools be thoroughly sharpened on an oilstone and that the cut be made in the same direction as the grain of the wood.

Suppose it is desired to chamfer the base for an inductance coil. The first step is to chisel roughly the wood from the edge as shown in Fig. 1, keeping the left hand well away from the point of the chisel and holding the wood firmly to the bench. A stop made from a piece of batten should be attached to the bench, to act as an abutment, and the baseboard rested against it. The chisel is held in the right hand and the thumb rested against the side of the baseboard to steady the chisel.

When the edge has been roughed out in this way the final levelling and smoothing is done with an ordinary smoothing plane manipulated as in Fig. 2. It is important to keep the plane at the same angle all the way along the edge, as if the plane is tilted more at one end than the other the chamfer will be uneven. A bevel square should be used to test the accuracy of the angle, and any necessary corrections made by careful local planing. Another way is to scribe lines along the top and side of the edge, parallel to the edge, and plane down to these lines. Their distances from the edge may easily be obtained for any angle by the use of a bevel square along the end of the wood.

The chamfer on a circular piece of wood is best carried out in a lathe, and this method is illustrated in Fig. 3, where the final cut is being taken on the bevelled

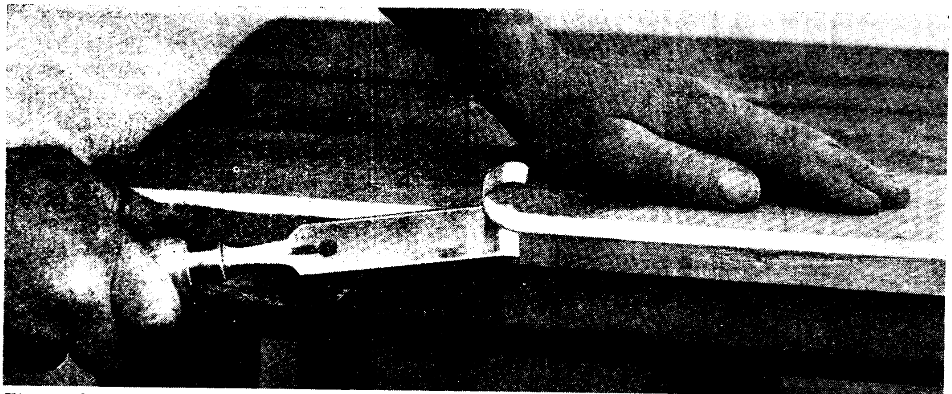


Fig. 1. Roughing out the base prior to planing may be accomplished with a chisel. Note the thumb pressed against the woodwork, acting as a guide to prevent the chisel slipping

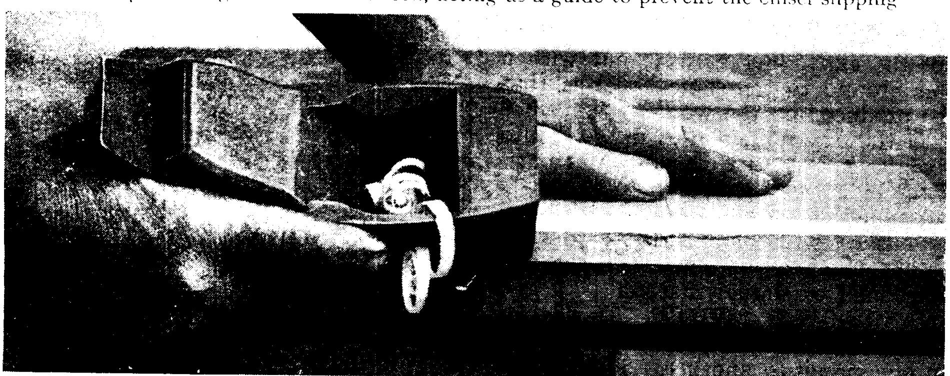


Fig. 2. After the rough edge is taken off a smoothing plane is used. The angle should be frequently tested with a bevel square

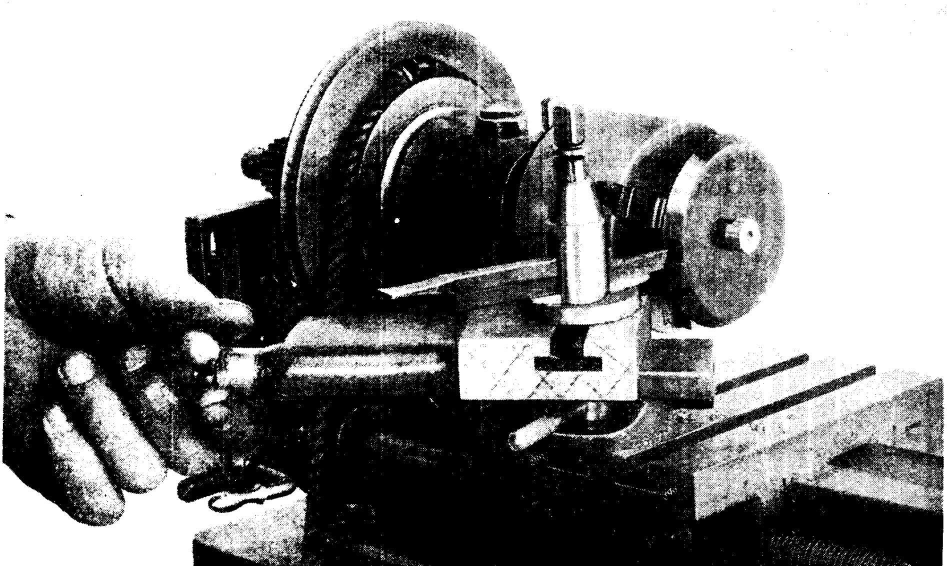


Fig. 3. Chamfering is here seen in progress, a lathe being employed. The edge of a condenser dial, being circular, would be difficult to chamfer by hand. The method adopted in this case enables very accurate results to be obtained

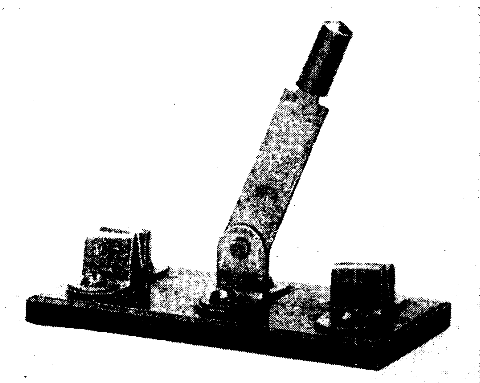
CHAMFERING BY HAND AND LATHE

edge of a condenser dial. The slide rest is set over to the correct angle and the tool traversed with the top slide lead screw in the usual way. In cases where a set-over top slide is not available the best result is generally obtained by the use of a former or tool with a wide cutting face ground off to the correct angle for the bevel. This is fed into cut with the lead screw and any slight adjustment made by manipulation of the top slide.

Bevels are turned easily with a hand tool in a plain wood-turning lathe, and on ebonite an ordinary round-nosed tool will answer. In the absence of a lathe the desired result is often obtainable by the use of a brace and bit. The latter should be of the expanding variety, but with a cutter ground to the same bevel as that to be produced on the work. The centre pin on the expanding bit is inserted into the centre hole in the dial, or other part, and the bit rotated steadily and as evenly as possible. The hole should be temporarily bushed with brass tube to prevent the pin damaging the bore when the dial is of ebonite or similar material.

CHANGE-OVER SWITCH. Device for changing the flow of current in a circuit, or from one circuit to another. This should not be confused with the reversing switch, which changes the direction of flow of current in a circuit.

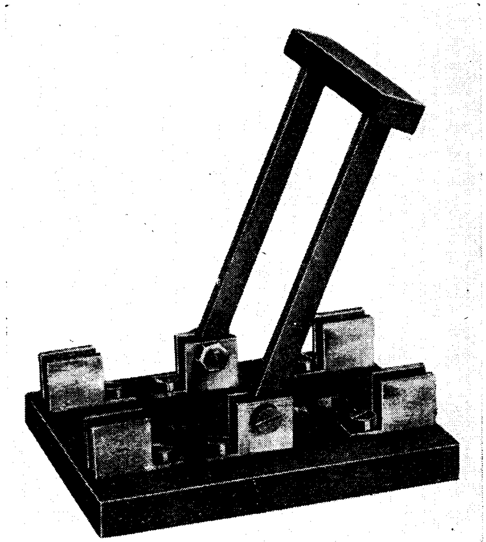
There are many applications of the change-over switch in wireless work, as, for example, the connexion of a condenser in an aerial tuning circuit. The function of the switch then is to connect the condenser in series or in parallel as desired, merely by throwing over the switch. A simple form



SINGLE-POLE CHANGE-OVER SWITCH

Fig. 1. Connexion between an aerial lead and one or two crystal detectors, for example, can be made by using a single-pole change-over switch

of change-over switch is illustrated in Fig. 1, which shows a single-throw single-pole switch. One application of such a switch would be to connect the aerial lead-in to one or other of two crystal detectors. The lead-in would be connected to the centre contact on which the lever pivots, and wires would connect from each of the other contacts to the detectors.



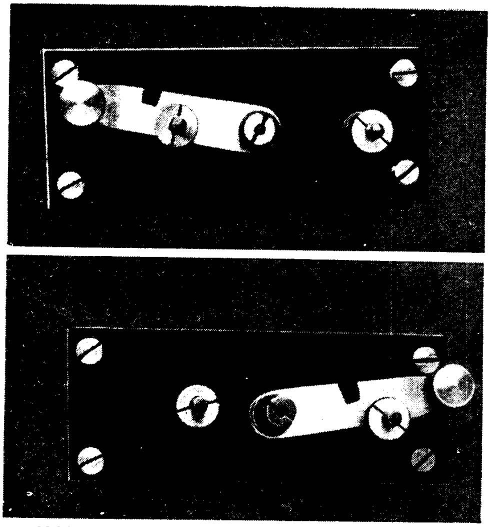
DOUBLE-POLE SWITCH

Fig. 2. Twin wires are connected or disconnected simultaneously by the use of a double-pole change-over switch, a form of which is here shown

When the switch lever is vertical the aerial is disconnected; when to the right one of the detectors is in circuit; and the other when the lever is thrown to the left.

A similar switch, when arranged to change the connexions of two wires, as, for instance, the positive and negative wires from a filament battery, is known as a double-pole double-throw switch; a typical example is illustrated in Fig. 2, and is connected and functions on the same principle as the former example. The applications of this class of switch to wireless circuits are shown in many of the diagrams in the pages of this Encyclopedia.

The construction of a simple switch for low-tension work need not entail much expense or labour. An easy method is illustrated in Figs. 3 and 4. This is made up of terminals on an ebonite base, the procedure being to cut the base to desired size and drill holes in the corners for the holding-down screws. The next step is to fix an ordinary terminal to the centre of the base, and two at unequal distances from it, one on each side as shown in the illustrations. The switch lever is cut from strip brass about ¾ in. wide and 2 in. long. This is filed to a taper and drilled



HOME-MADE CHANGE-OVER SWITCHES

Fig. 3 (above). Switches for change-over purposes can be made as above by the amateur. The lever is cut from strip brass. Fig. 4 (below). Compare this view with Fig. 3, and it will be seen that the terminals are unevenly spaced. These are arranged to take the notches in the lever

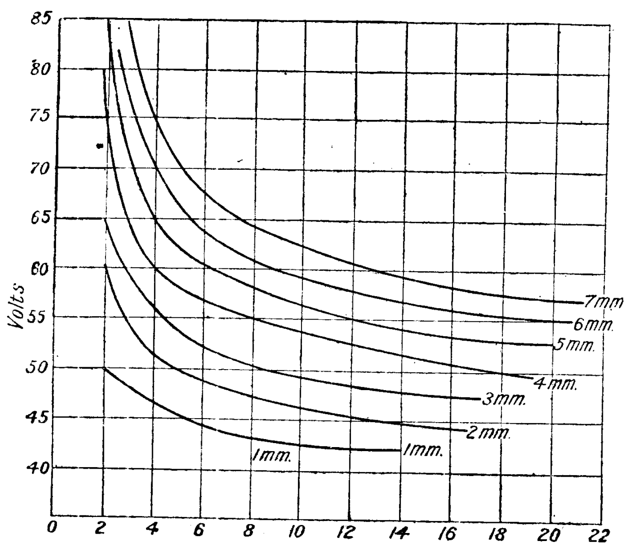
at one end to fit easily on the terminal in the centre of the base. The outer end is provided with an ebonite handle, and slots are cut on opposite sides of the lever to fit on to the other terminals.

The centre terminal nut is locked with a lock nut or other means. The outer terminals are plain, and in use the switch is thrown to one or the other of them. The terminal nut is then tightened on to the lever and a perfect electrical connexion is the result. This makes a neat and effective switch for panel mounting. The connecting wires can be taken beneath the panel and are similar to the first example. The same idea can be applied to a double-pole switch, or a series can be arranged on the panel and numerous circuits controlled with them. In Fig. 3 the lever is shown in the left-hand position and in Fig. 4 in the right-hand position, making the location of the slots clear, also the importance of the unequal spacing of the slots for the terminals.

CHARACTERISTIC CURVE. Any curve which graphically represents a change in condition or other change in the functioning of a piece of machinery, a material, etc., under varying conditions. A curve showing the increase of temperature of a conductor as the voltage increases would be a curve for such conditions, and a general curve showing the usual characteristics of a rise in temperature plotted against voltage would be a characteristic temperature-voltage curve for wires, for example.

In wireless the term characteristic curve is usually confined to the characteristic curves of valves, crystals, etc. The characteristic curves of valves and crystals are separately described.

The figure shows the characteristic curves of an arc. The curves are obtained by maintaining the arc length constant, varying the current passing through it, and measuring the potential difference between the terminals. The curves are due to H. Ayrton, and are plotted for arc lengths of 1 mm. to 7 mm. It will be



CHARACTERISTIC CURVE

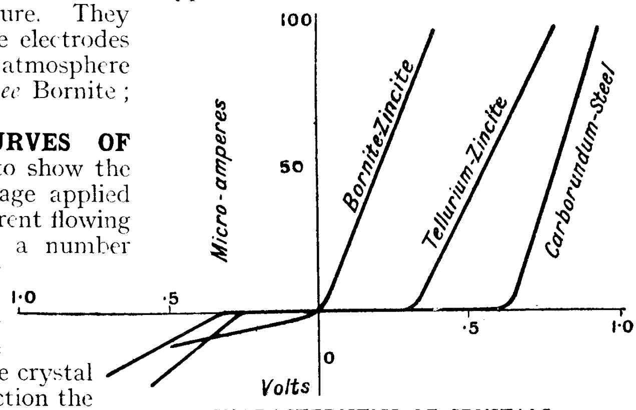
Graphical representation of change in condition plotted diagrammatically is usually in the form of lines on squared paper, as in this example, which shows how the voltage in carbon arcs drops as the amperage increases observed that from these curves it may at once be stated that as the current (amperes) increases the potential difference (volts) between the terminals falls. The curves are for solid carbon rod electrodes, and they are important, for they show that the resistance falls off as the current is increased, exactly opposite to the usual law holding. The general form of the curves are shown in the figure. They differ slightly according to the electrodes used, and also according to the atmosphere in which they are burnt. *See* Bornite; Carborundum.

CHARACTERISTIC CURVES OF CRYSTALS. Curves plotted to show the relationship between the voltage applied to certain crystals and the current flowing through them. Fig. 1 shows a number of characteristic curves for various crystal combinations. From these curves it may be seen at once that when voltage is applied to a bornite-zincite crystal combination in a positive direction the resistance of the crystal is low, but when applied in a negative direction the resistance increases much more rapidly. In the tellurium-zincite combination no current at all flows on the positive side until about 0·3 volt is applied; and for carborundum-steel, 0·7 volt is required. The curves show clearly that the crystals offer more resistance to the flow of current in one direction than in the opposite.

These curves must not be taken as absolute, but as showing the general form which is obtained. One specimen of crystal differs from another, and the characteristic curve varies accordingly.

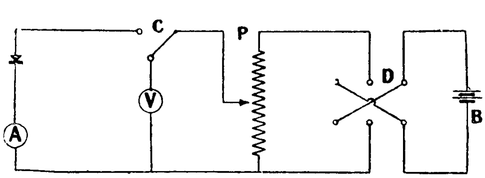
The steady current which is applied to the crystal through a potentiometer should be about equal to that where the characteristic curve turns sharply upwards, *e.g.* at a little more than 0·3 volt in the case of tellurium-zincite. This gives the most sensitive condition for reception purposes. The best form of curve is that which turns up sharply on one side of the origin and is as flat as possible on the other side, for this gives the greatest rectification.

Only small voltages have actually been applied to obtain the curves shown in the figure, but large ones might also be applied. In the case of a carborundum crystal, for example, 10 to 30 volts might be applied, and rectification improves.



CHARACTERISTICS OF CRYSTALS

Fig. 1. Several crystals having been tested by the arrangement shown in Fig. 2, their characteristics are shown in curves and can therefore be compared



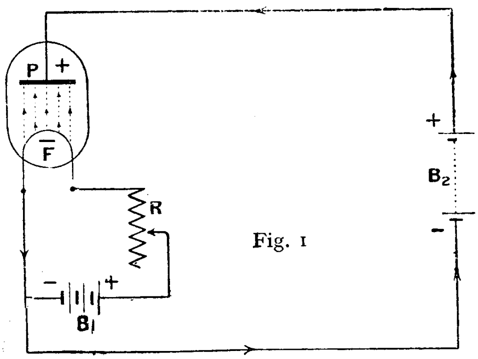
TESTING A CRYSTAL'S RESISTANCE

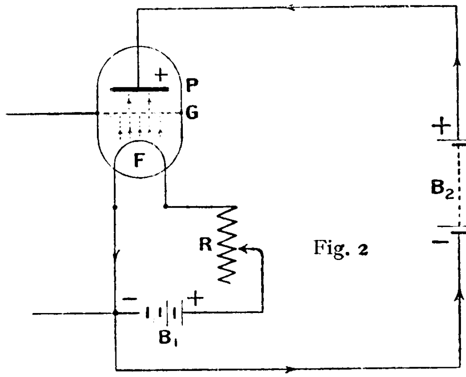
Fig. 2. In order to obtain the characteristic curve of a crystal an arrangement including an ammeter a voltmeter, a potentiometer, and battery, is used to determine the amount of resistance the crystal will offer when the current is applied alternately positively and negatively

Fig. 2 shows how the characteristic curve of a crystal may be obtained. P is a potentiometer of 200–400 ohms resistance, B a small dry battery, A and V a micro-ammeter and high-resistance voltmeter respectively. D is a reversing switch to the battery and the potentiometer, C a switch which connects to the ammeter and voltmeter.

To obtain points on the curve begin by setting the potentiometer to some voltage determined by the voltmeter, closing the switch C to do so. Then switch C to the ammeter and detector circuit, and read the current in A. By repeating the operation for various voltages, points may be obtained on the curve connecting the galvanometer readings with the ammeter readings. The battery is then reversed, and the readings taken through the crystal in the opposite direction and the full curve plotted, enabling the characteristics of several crystals to be compared. *See* Crystal.

CHARACTERISTICS OF VALVES. What is usually understood by the characteristic of a valve is the curve showing the relation between the potential at its





PRINCIPLES AND CHARACTERISTICS OF THE THERMIONIC VALVE

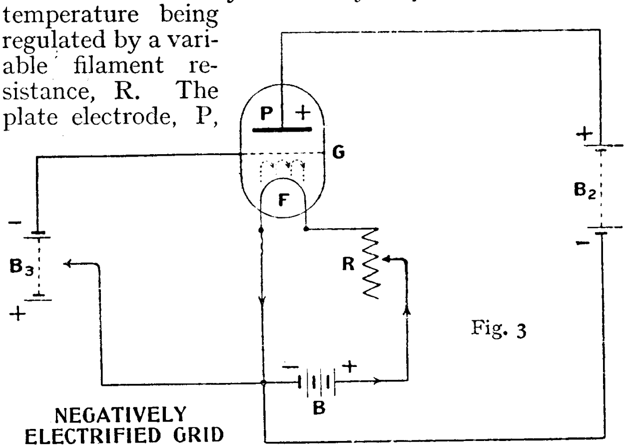
Fig. 1 (left). Flowing from the filament F to the plate P is a stream of electrons, indicated by arrows. This is the path which is opened up for the passage of current in a two-electrode valve. Fig. 2 (right). Between the plate and the filament is a third electrode or grid. A certain number of electrons are arrested, and the grid potential lowered in consequence

grid electrode, and the resulting current from the plate electrode.

If a simple two-electrode valve is first considered, such as shown in Fig. 1, its fundamental action may be briefly set out as follows. The filament, F, is brought to incandescence by a battery, B_1, the temperature being regulated by a variable filament resistance, R. The plate electrode, P, is kept at positive potential by the fact of being connected to the positive pole of a high-voltage battery, B_2.

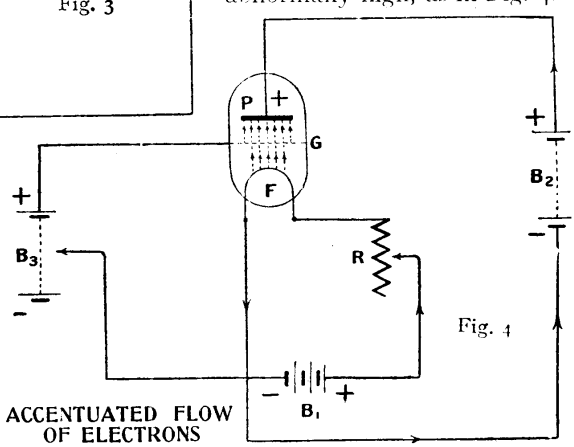
When F is heated from the battery B_1, a cloud of electrons is emitted which is attracted to the positively electrified plate, P, as shown by the small arrows, which allows current to flow continuously from P to F in the direction impelled by the high-voltage battery B_2. If, now, a third electrode or "grid" is inserted between F and P, as in Fig. 2, it captures a certain number of electrons in their passage from F to P, and its potential becomes lowered.

The flow of current from battery B_2 through P to F is consequently reduced. If the grid, G, is negatively electrified by some external source, such as another battery, B_3, shown in Fig. 3, the flow of electrons from F to P may be still more reduced or even completely obstructed, as shown by the small arrows. But if the grid, G, is positively electrified, the flow of electrons is accentuated and becomes abnormally high, as in Fig. 4.



NEGATIVELY ELECTRIFIED GRID

Fig. 3. Negative current being applied to the grid, the flow of electrons from filament to plate is completely obstructed



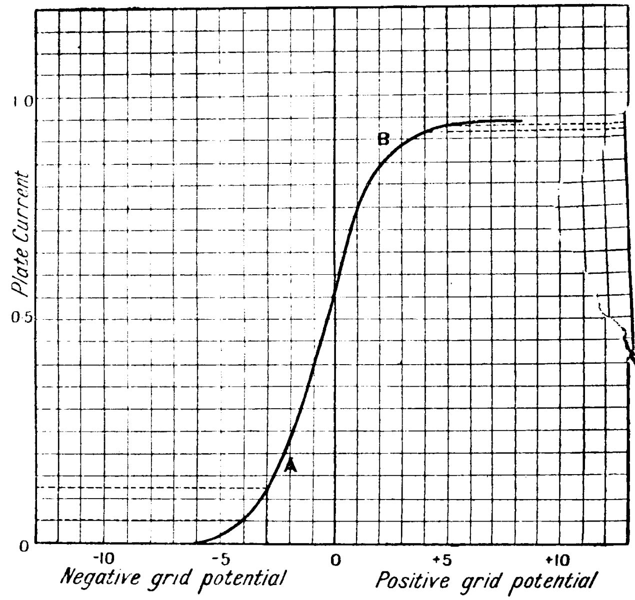
ACCENTUATED FLOW OF ELECTRONS

Fig. 4. In this case a positive current is supplied to the grid, and instead of the flow of electrons being checked it is accentuated, as indicated by arrows

These variations between grid potential and resulting plate current are known as the characteristic curve of the valve when plotted against one another as in Fig. 5.

The circuit for obtaining valve characteristics and a diagram of connexions is given in Fig. 6. A potentiometer at P_1 varies the grid potential either in the positive or the negative sense. B_2 is a battery for the plate electrode variable between about 50 and 200 volts, and A is a milliammeter. The filament current is supplied from battery B_1, and controlled by a variable filament resistance of about 10 ohms.

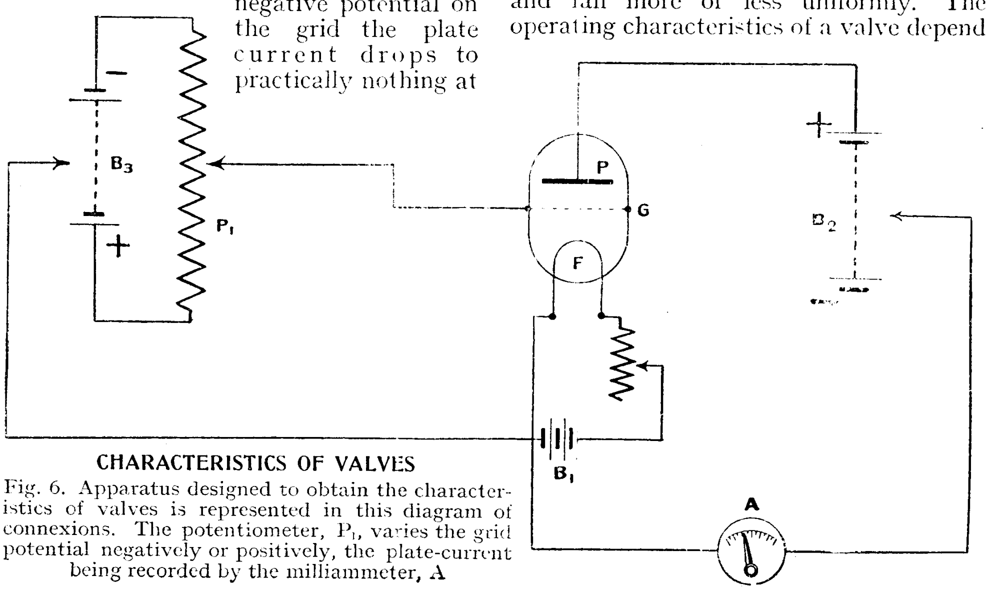
A curve obtained from this test is illustrated in Fig. 5, and is obtained by keeping the voltage of the battery B_3 at a constant figure, but changing the grid potential from positive to negative. The results will not, of course, be the same for all valves, as there are slight differences in construction, but Fig. 5 is a good typical curve.



CHARACTERISTIC CURVE OF A VALVE

Fig. 5. Differences in manufacture and types of valves result in different curves being obtained. Here is a characteristic curve of a valve tested by the circuit represented in Fig. 6

It will be noticed that the plate current with this particular valve reached its maximum when the grid was charged to 5 volts positive potential, and with 6 volts negative potential on the grid the plate current drops to practically nothing at all. Between these two extremes lies a comparatively straight portion of the curve, AB, where the plate current responds almost directly in proportion to any decrease or increase of potential on the grid. Anywhere in this region, therefore, an alternating current impressed upon the grid will cause the plate current to rise and fall more or less uniformly. The operating characteristics of a valve depend

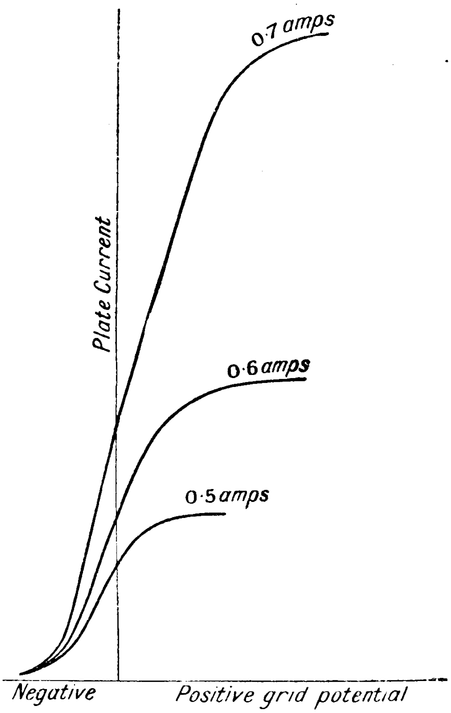


CHARACTERISTICS OF VALVES

Fig. 6. Apparatus designed to obtain the characteristics of valves is represented in this diagram of connexions. The potentiometer, P_1, varies the grid potential negatively or positively, the plate-current being recorded by the milliammeter, A

entirely upon that portion of the curve at which it is being worked.

If, for instance, the grid had been adjusted to a fairly high negative potential, such as 4 volts, a relatively slight decrease of grid potential would give rise to a large increase in the plate current. If, however, the grid potential had been increased, the resulting decrease in plate current would have amounted to much less. In other



EFFECT OF DECREASED TEMPERATURE

Fig. 7. Alteration in the characteristic curve of a valve takes place, as will be seen above, by an increase or decrease in temperature

words, the amplitudes of increased plate current far exceed the amplitudes of decreased plate current when working on this portion of the valve characteristic. Had the valve been working on the upper extremity of the curve, however, exactly the reverse would have taken place, that is to say, increasing the grid potential would have had a far smaller result on the plate current than decreasing the grid potential.

The way in which these effects are turned to account when the valve is operating as a receiver may be explained thus. The grid current consists of a stream of negatively charged particles drawn off from the filament, so that its effect is to neutralize partly the positive charge on the grid. The result of superposing an alternating wave from an incoming signal on the grid circuit is to cause it to alternate from positive to negatively charged condition and cause an unequal variation in grid voltage above or below the normal. When worked on the lower part of the characteristic, the amplitude of plate current due to the negative increase of grid potential is so much smaller than the amplitude of plate current due to the positive increase of grid potential that a rectifying effect is produced and the resultant currents take a practically unidirectional form.

The shape of the valve characteristic may be considerably altered by an increase or decrease of the temperature of the filament, as indicated in Fig. 7. These curves show the effect of increasing the filament current of a certain valve from 0·5 to 0·6 and 0·7 amperes respectively, and incidentally they bring to light the fact that as the temperature of the filament increases the grid potential must also increase in order to bring the plate current to "saturation" point, which is the point at which increasing the grid potential is found to have no further appreciable effect on the plate current. On the curves shown this is the point where their upper extremities begin to turn over abruptly.—*A. H. Avery, A. M. I. E. E.*

See Anode; Grid; Valve.

CHARGE. In electricity, an excess or deficit of electrons on an insulated body. When a body is in a neutral condition, that is, when there is no excess or deficit of electrons, the body is said to be discharged or to be in an unelectrified state. When there is an abnormal number of electrons on a body a strain is set up in the ether. The simplest experiment to show such a state is to rub an ebonite ruler or a length of glass rod with a piece of flannel. If the rubbed part is held near light objects, as small pieces of tissue paper, they are attracted.

The ebonite is electrified. A brass rod may be similarly electrified by friction, but since the rod is a conductor of electricity, the latter flows through the body to earth and the rod remains electrically normal. If the brass rod were insulated, however, it would act in the same way as the ebonite rod. *See* Electron.

CHARGING BOARD. A charging board is a form of switchboard used in connexion with the control of electric accumulators. While the switchboard of a house-lighting plant which has a battery of accumulators to supply current when the engine is not running is sometimes called the charging board, the term is more usually applied to a panel arranged with switches, fuses and resistances, to reduce the high-pressure current supplied to a strength suitable to pass through an accumulator or series of accumulators.

The nominal voltage of an accumulator cell is two volts, actually 1·8 volts when completely discharged and 2·4 volts fully charged. From the practical point of view the house supply mains are mostly of 200 or 220 volts. To employ this current direct would involve the use at one time, and connected in series, of about 100 separate cells. As a rule it is not convenient either to instal or to collect so many cells for charging at one time. Some means of reducing the current must therefore be devised.

Direct Current Essential

If, say, 200 volts were impressed on a single accumulator cell, the flow of current would be 100 times the normal amount, and there would be an immediate " burn out " owing to the low resistance of the accumulator. While voltage would be the prime cause of the trouble, the actual damage is done by what may be termed the volume, *i.e.* the amperage, of the current which the high pressure forces through it. As a rule the charging rate of a particular cell is stated on its label, and this varies exactly as the size. An accumulator with twice the plate area of another will take, and deliver, twice the amount of amperage current.

The voltage is, however, the same for any cell. The flow of current from an accumulator is unidirectional, that is to say, it is a piece of apparatus delivering a continuous current. Under charge the current runs the opposite way but is continuous. Therefore only a direct or continuous current supply can be utilized. An alternating current is of no use whatever unless it is rectified. The pulsations of an alternating current circuit would equally charge and discharge the cell, and nothing would happen to the accumulator connected to the circuit.

In arranging to cut down a house supply to suit the accumulator it must be remembered that the high-pressure mains of a certain voltage will push through a given circuit a current of a fixed amperage, which amperage is comparable with the resistance the voltage encounters. A cell may have a resistance measured only as a fraction of an ohm and a back electromotive force (*q.v.*) which cannot exceed 2·4 volts. Taking the total opposition to the flow of the charging current at $1\frac{1}{4}$ ohms, a 200-volt circuit would under the fundamental law

$$\frac{\text{voltage}}{\text{resistance in ohms}} = \text{current (amperes)}$$

pass a current of

$$\frac{200 \text{ (volts)}}{1\frac{1}{4} \text{ (ohms)}} = 160 \text{ amperes,}$$

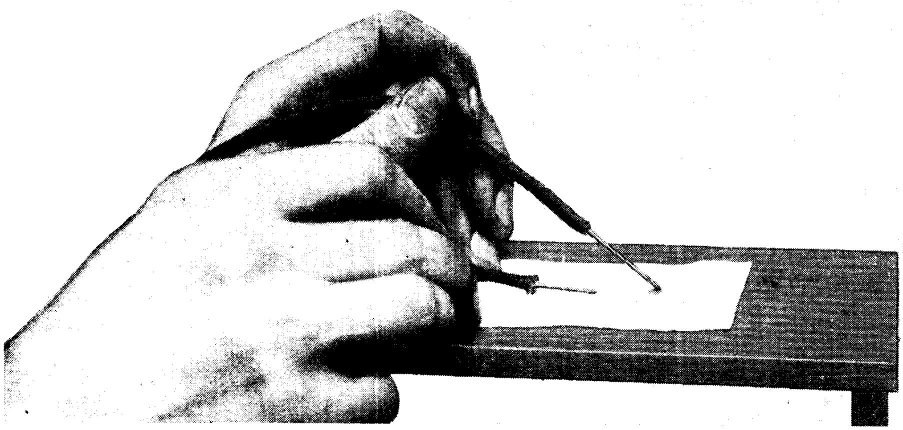
which would destroy it completely. Now a 32 candle-power electric lamp of the metal filament type has a resistance of several hundred ohms, and would at the 200 volts pass about one-eighth of an ampere. An old carbon lamp of the same illuminating value, not being so economical, would take just over half an ampere. It is an axiom that the amperage, whatever it may be, is, at any one time, the same in all parts of an electric circuit. If the resistance in series inserted is such that the amperage passing is a known quantity, then by placing an accumulator in the circuit the same current will go through it in the opposing direction, and an amount equal to the watts absorbed will be accumulated.

A watt is a measure of the amount of an electric current and is determined by the amperes × volts. The watts consumed in the lamp will be $\frac{1}{8}$ ampere × 200 volts = 25 watts, and in the accumulator $\frac{1}{4}$ watt. The total amount passing will be $25\frac{1}{4}$ watts.

Using the House Lamps as Resistance

It will be seen that the light consumes many times the value of that absorbed by the accumulator ; therefore, to use the lamp for no other purpose than a resistance protecting the accumulator from a dangerous charge of electricity is costly. The lamp should, if economy is to be considered, be one which has to be used in any case, and the charging restricted to times when the lamp must be alight. Certainly the value of the light is reduced, but only in a very small proportion.

Of course, it is quite possible to run the current through an ordinary wire resistance, but it is not such a practical proposition. The apparatus is cumbersome compared with the ordinary incandescent lamp. The electric stove, should



POLARITY TEST WITH POLE-FINDING PAPER FOR CHARGING

Fig. 1. Litmus or pole-finding paper is used to obtain an indication of the polarity of current in a charging board. The paper is made quite damp and laid on a slab. When the paper turns red at the contact point negative polarity is indicated

one be installed, can be used as a resistance instead of the lights, and in that case the heat may be useful. Another feature in a charging board is the provision of a detector for obtaining an indication of the polarity of the current. As already mentioned, it is necessary for the positive terminal of the supply to be connected to the positive terminals of the accumulator, that is to say, the currents must oppose and the superior potential, or electromotive force, of the supply so force the electricity through the cell. Otherwise with an opposite connexion the accumulator will be drained of what little charge it contains, or, as it is termed, "milked." To obtain such an indication there are several methods which may be adopted.

By using a litmus, or "pole-finding," paper, which is made quite damp and laid on a wooden slab or other insulator, a chemical reaction shows the polarity by turning the contact point of the negative wire on the paper red. The photograph, Fig. 1, shows how this is done.

In place of the special pole-finding paper, a strip off a blue print drawing may be used. In testing, the paper is also moistened and the two bare wires placed on it. The dark blue of the paper changes to a yellowish-white at the negative pole.

The magnetic indicator used to find the polarity of the current is virtually a small galvanometer (*q.v.*). The magnetized needle is painted with one half of the hand black and the other end left bright. An incandescent lamp is placed in the holder and the plug on the end of the flexible wire placed in any convenient lamp socket. With the current switched on the lamp will not light until the terminals are short-circuited by an accumulator or a wire. For testing a wire should be used, and immediately the circuit is completed the needle on the indicator will swing over in a line from terminal to terminal. The internal winding of the galvanometer is so arranged that the black end of the needle in swinging over points to the positive terminal. This terminal is then connected to the positive of the accumulator.

With a single lamp holder the following charging rates may be obtained according to the varying voltages and carbon filament lamps.

Charging rate in amperes for one carbon lamp.	Candle-power of lamps at different voltages.		
	100 V.	200 V.	220 V.
·25	—	—	16
·3	8	16	—
·4	—	—	25
·5	—	25	—
·6	16	32	50
·8	—	—	—
1·0	25	50	32
1·25	32	—	—

NOTE.—Metallic filament lamps take only one fourth of the amperage of carbon lamps; therefore, to obtain the same charging rate, lamps of four times the candle-power will be required.

To obtain a larger charging rate at any one supply voltage, additional lamps may be inserted in parallel, not in series. There is no need to fit up separate switches in connexion with these lamps, as the charging rate can be varied by taking the lamps out of their sockets. If more than one accumulator has to be charged these should be connected in series, the positive terminal of the first to the positive terminal of the supply, and the negative of the last cell to the negative of the supply. The intermediate connexions of the accumulators would be negative to positive in each case.

How to Make a Single-Lamp Charging Board. The object of this charging board is to reduce the current from ordinary house-lighting circuits to a sufficiently low value to charge small accumulators.

There are two types of current supplied for house lighting: (1) direct current, (2) alternating current.

Direct current only is suitable for this board.

Materials required:

One block of well-seasoned wood, 8 in. by $4\frac{1}{2}$ in. by 1 in. preferably teak, oak, or beech.

One flanged type lamp holder.

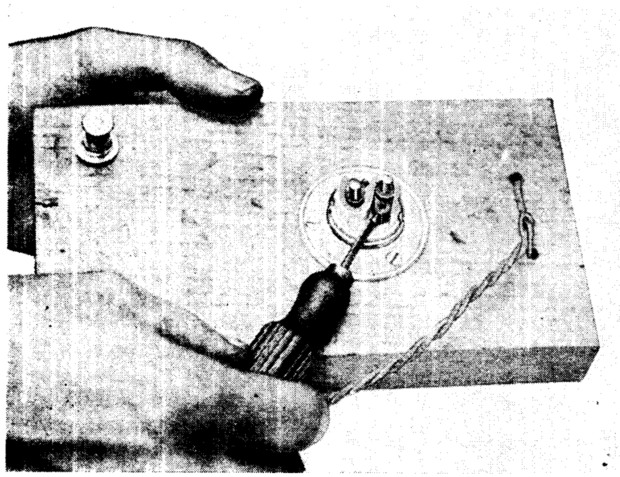
Two large terminals.

Short lengths of insulated wire.

One carbon filament lamp.

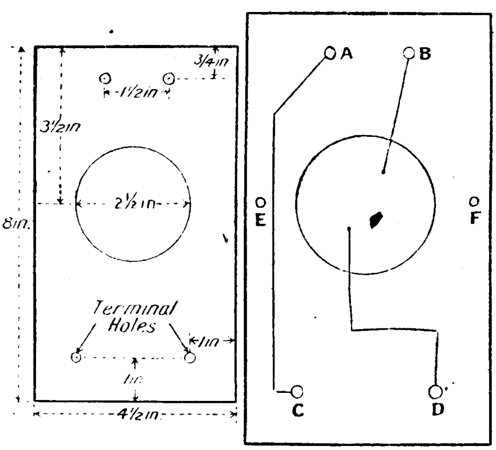
After shaping up the block of wood to the sizes shown in Fig. 2, it can be drilled to take its two terminals. If difficulty is experienced in obtaining terminals with shanks long enough to go through the wood, either countersink the holes in order to take the terminal nuts, or choose a thinner base. It is preferable, however, to use a thick base, as in the event of a partial short circuit and consequent heating, a thick base will not so readily catch fire as a thin one.

Two holes, $1\frac{1}{2}$ in. apart, are drilled $\frac{3}{4}$ in. from the top of the board (Fig. 2). These holes enable the flexible wire to be carried through underneath the board. The lamp holder is placed in the centre



LAMP-HOLDER FOR CHARGING BOARD

Fig. 4. Screwed to the centre of the board is a lamp holder. A wire is being clamped by the small screw engaged by the screwdriver



MAKING A SINGLE-LAMP BOARD

Fig. 2 (left). Dimensions as here given may be used in making a single-lamp charging board. Fig. 3 (right). Wiring of the board is here represented, the diagram being of the underside

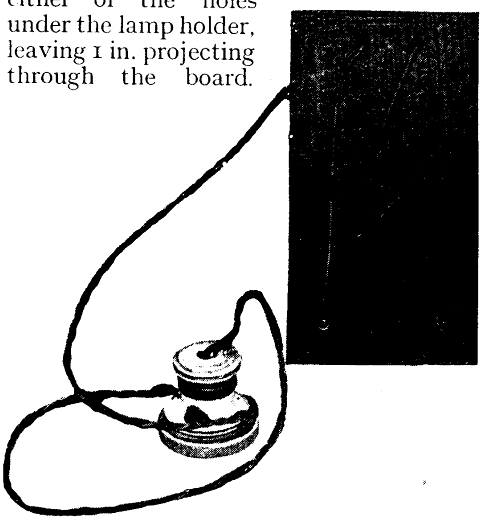
of the board, $3\frac{1}{2}$ in. from the top. It is fastened to the board by two or three brass wood screws, Fig. 4, having countersunk heads. Holes in the flange of the lamp holder are provided for this purpose.

A knurled ring will be found on the lamp holder near its flange. Unscrew this and remove the brass top portion (in which the slots are cut). A porcelain holder containing two spring contacts will be found inside the lamp holder. Each contact piece will be found to have a small screw in the side of it. This screw should be withdrawn until it does not obstruct the hole visible from top and bottom of the porcelain.

Two flutes will be found opposite each other in the side of the porcelain. Put the porcelain back into the flanged base so that the two flutes register with two indentations in the flanged base. By inserting a fine knitting-needle down each of the two holes, the position can be found for drilling the holes through the base.

These two holes are required to take the wire to the contact pieces of the valve holder. Cut off sufficient lighting flex to reach from the wall plug and socket (Fig. 5) to the position where it is desired to use the charging board. Untwist about a foot of the flex, and push the wires through holes A and B, Figs. 3 and 6, from the top side of the board.

One of these wires is now drawn through either of the holes under the lamp holder, leaving 1 in. projecting through the board.

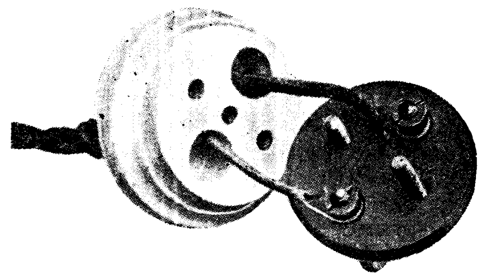


BACK OF CHARGING BOARD

Fig. 6. Connexions may be seen on the back of this single-lamp charging board, also the plug and socket

The insulation should be taken off to a depth of nearly $\frac{1}{2}$ in. Replace the porcelain, allowing the bare wire to just project through one contact piece. Now screw up the clamping screw, which ensures good electrical connexion between one flex and the contact strip. Using a foot of the wire, repeat this operation through the second hole of the porcelain.

The free end of this wire is clamped under the nut of terminal D (Fig. 3), the insulation being stripped on the wire underneath the nut. Two indentations in the top of the lamp holder, similar to those in the base, will be found.



PLUG FOR CHARGING BOARD

Fig. 5. Charging-board plugs are very similar, as will be seen, to wall plugs. The front has been unscrewed to show the method of wiring

These should also register with the flutes in the porcelain. When this is done, replace the knurled ring and screw up tight.

It is very important to see that the indentations really do coincide with the flutes in the porcelain. Unfortunately, the great majority of lamp holders, especially the cheaper ones, can be screwed up without this necessary registration. The result is that no lamp will light in them when wrongly assembled, as the contact pieces will not register with the contacts on the lamp.

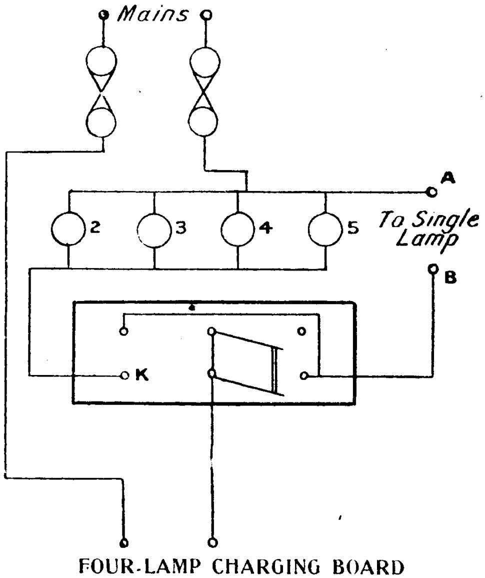
CHARGING BY ONE-LAMP BOARD

Fig. 7 Earthing is prevented by mounting the lamp on an insulated board raised by two other boards, as seen above. A 6-volt accumulator is being charged

This done correctly, the wiring will be finished on connecting the remaining flex lead to the terminal still disconnected. If a suitable wall socket is available already wired up to the lighting system, this may be used. The free ends of the flex should be bared of insulation, as was done in the case of the lamp holder. They should now be fitted into a plug capable of being inserted into the wall socket. This need not be described in detail, as the operation has already been dealt with in connecting the lamp holder.

If no wall socket is available obtain a lamp-holder plug and connect up the flex to this. This is also a repetition of the operation of wiring up the lamp holder, and needs no further comment.

The lamp to be used should be of high candle-power. It depends, of course, on the charging rate of the accumulators, but this board is suitable for small accumulators only. Owing to the comparatively low current available from the one lamp, charging large accumulators would be a very long process. A simple method of



FOUR-LAMP CHARGING BOARD

Fig. 8. Heavy currents can be dealt with by this four-lamp board as well as the supply of a small charging current from a single lamp when required

determining the current from a carbon lamp of given candle-power is to multiply the candle-power by five, and divide the result by the voltage of the lamp. This voltage is naturally the same as the voltage of the mains.

The charging board is now ready for fixing into the position it is intended to occupy permanently. Two screw holes can be drilled, as E and F in Fig. 3. Place two strips of wood behind the board at top and bottom. These will be held in position when the charging board is screwed down, and will prevent squeezing the wires at rear of panel.

During the charging process (Fig. 7) the accumulator should stand on a perfectly dry piece of wood or other efficient insulator to guard against earthing—that is, a leakage of current from the accumulator due to the possible dampness caused by the sprayings of acid or otherwise. Should such an earth be completed, the fuses will blow or a fire will be started.

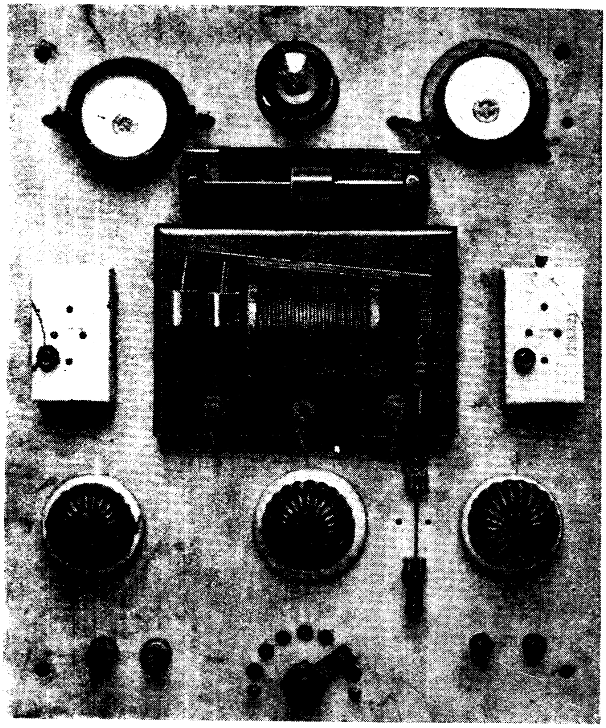
The charging-board wiring shown in Fig. 8 has the great advantage that, although capable of dealing with fairly heavy currents by the four lamps wired in parallel, it can supply a small charging current from a single lamp. This lamp need not be on the charging board at all. Many people keep a hall lamp burning all night, and if it is possible to requisition the services of a lamp nearly always, or very often, burning, it can very easily be persuaded to perform another duty. This is to supply a slow charge to a cell or a battery of cells. This will have the good effect of minimizing sulphation and keeping the cells in good condition. There are two fuse boxes shown at the top of the board (Fig. 8), but unless the charging-board wires are taken direct from the meter or main fuses, they may be omitted.

Numbers 2, 3, 4, 5 are four carbon lamps wired in parallel. It will be seen they are connected with one side of mains and also to one terminal. With the other terminal adjoining it (A and B) they form binding posts to which the single lamp connexions are made. This lamp is, of course, not on the board. The other side of the four parallel lamps is taken to bottom left-hand contact of K, a double-pole change-over switch. The remaining single lamp terminal connects the top left-hand contact with the bottom right contact. The two centre contacts holding the switch arms are joined together and taken down to one side of accumulator terminals. The circuit is now completed by wiring remaining accumulator charging terminal to the remaining supply terminal.

When the switch arms of K make contact with the top contacts only the single lamp will supply current, but on changing the switch to the lower contacts all five lamps will be introduced, giving a heavy current value.

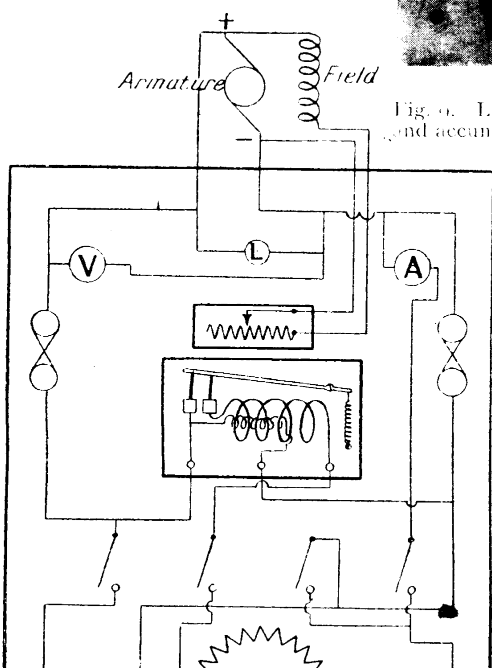
Another advantage of this type of switch is that all lamps will be switched off on opening the switch. It is best to put the switch on the charging board sideways. This will prevent an accident if the switch arms worked loose and dropped down to the lower contacts.

A Low-voltage Charging Board. The charging board illustrated in Fig. 9 is made for use with a small power-generating plant, consisting of a $\frac{1}{3}$ h.p. gas engine and a 30 volt 5 ampere dynamo. Provision is made



LOW-VOLTAGE CHARGING BOARD

Fig. 9. Lighting terminals are seen on the left of the board and accumulator terminals on right. This type of board is used with a small power generator



CHARGING-BOARD CONNEXIONS

Fig. 10. Wiring of the board shown in Fig. 9 is represented in this diagram. Current is varied by the resistance, which has seven tappings. An automatic cut-out is included

for lighting lamps straight off the generator if required, whether charging is in progress or not. To vary the current for charging purposes, a resistance with seven tappings is used, it being considered more convenient than the usual lamps for this low-voltage purpose. An automatic cut-out is fitted to prevent the accumulators discharging through the dynamo should the engine fail while unattended, and a dynamo field resistance, or regulator, is another useful fitment. The circuit diagram is given in Fig. 10, and the wiring on the back of the board in Fig. 11.

By careful adjustment of the cut-out it was made to cut in automatically as soon as the engine was started. As an additional protection against mishaps two main fuses are fitted, which blow at 7 amperes. The board is fitted with voltmeters and ammeters, and a pilot lamp of 10 c.p. is always in circuit to show from a distance if the plant is working. It also serves to illuminate the board at night.

The cut-out is of the mercury-break type and has two windings. First there is a primary shunt winding of fine wire, and a series winding of heavy wire placed in the charging circuit (outside). Reference to the circuit diagram (Fig. 10 and Fig. 11) will show exactly how this is arranged. Being of the mercury-break type, the cut-out must always be placed in a vertical position.

The field regulator is merely a resistance coil with a slider, to give any desired resistance at will. The board is made of marble; the top of an old wash-hand stand will do excellently. Marble is quite easy to cut with a hack-saw. Should it be desired to polish the edges, after cutting, this may be done with pumice powder and rottenstone applied with a wet cloth.

Marble can always be cleaned and whitened by rubbing it with a cloth soaked in dilute sulphuric acid, or if this is not obtainable, vinegar is quite a good substitute. No dimensions for holes in the board are given, as these must be made to suit individual requirements. Marble may be drilled quite satisfactorily with ordinary twist drills, although here, again, it is advisable to use old tools for, owing to its abrasive nature, it tends to grind the clearance on the sides of the drill flutes away very quickly. Large holes will be drilled with greater ease if a small hole is drilled first, in order to give the large drill-point clearance.

Holes for threading the wire through must be drilled where necessary, for many of the components on the board have terminals fitted on the front. Some of these may be obviated by purchasing instruments with back connexions. The resistance is of 20 gauge Eureka wire wound upon a porcelain former. The latter being hollow, a metal rod threaded at each end passes through it. The whole resistance is fixed to the back of the board by two brass angle brackets. They, in turn, are bolted to the board, the bolt heads being concealed by the tumbler switches. The four switches have the following purposes. Starting from left:

(1) Closes or opens circuit to left-hand terminals, allowing lighting direct from dynamo.

(2) Positive side of charging circuit.

(3) Closed, completes charging circuit, but no current flows through ammeter.

(4) Also completes charging circuit, but ammeter is now in circuit.

A two-way switch could take the place of (3) and (4), but the board was made up entirely of materials at hand to show what may be done by the amateur experimenter. This also accounts for the odd knife switch. The voltmeter is a high-resistance instrument and is always in circuit. Under no circumstances must a cheap low-resistance instrument be used, as it would consume quite a large amount of current. An assortment of odd screws and nuts is very handy in making this or any wireless apparatus, as practically every component requires a different size.

There is no real objection to bolts projecting at the back of the board for,

HOW TO WIRE THE CHARGING BOARD

Fig. 11. At the bottom of the board will be seen the back of a switch with wires connected to a resistance, which is tapped seven times. The two wires projecting at the top lead to the dynamo

in the final fixing to a wall or wherever it is to be placed, provision must be made to leave ample space at the back. The resistance wire at the back gets quite hot, and therefore must not be allowed to come into contact with anything. The fitting of the stud switch should present no difficulty, particularly if the front of the board is fairly flat.

As most marble slabs are at least $\frac{5}{8}$ in. to $\frac{3}{4}$ in. thick, it is possible that the contact studs usually sold for wireless purposes will be too short in the stem. Should this be the case, long cheese-headed screws may be used with the slotted portion turned or filed away. After fixing all the studs in place, they must all be brought to the same height. Filing them with a handle-less file is a fairly difficult job; but an easier way is to stretch a piece of coarse emery cloth tightly round a perfectly flat piece of wood and then to work it to and fro over the studs. A final rub with fine cloth will finish the job. The switch arm works in a central brass bush. This bush has a brass plate sweated to it as shown in Fig. 12. A bolt passed through each of the holes in this plate and then through the marble will fix it satisfactorily.

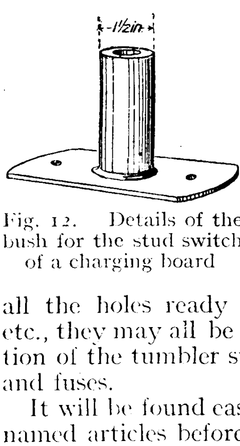
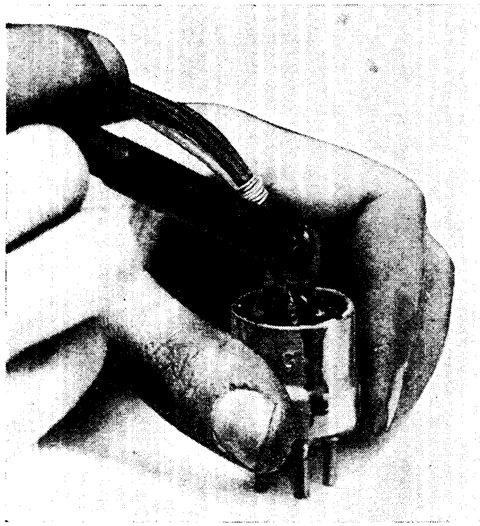


Fig. 12. Details of the bush for the stud switch of a charging board

Having drilled all the holes ready for the components, etc., they may all be fixed with the exception of the tumbler switches, lamp holder, and fuses.

It will be found easier to wire these last-named articles before fixing, owing to the difficulty of clamping the wires when they are in position. All joints in the wiring should be soldered, because the heat rising from the resistance soon oxidizes them and thus forms a skin of high resistance around the wire. If instruments with cases similar to those in the photo are fitted, care must be exercised in seeing that the bared ends of the wire do not touch the metal flange. It is also important to get the correct polarity for them, as already explained in the beginning of the article. *See* Accumulator.

CHATTERTON'S COMPOUND. Name given to a valuable insulating material of considerable utility to the wireless experimenter. It is composed of resin, Stockholm tar, and gutta-percha and is put up in the form of a stick. It is fairly soft, but is melted by gentle heat when it is desired to run it into a crevice or other inaccessible position.



USING CHATTERTON'S COMPOUND

An old valve holder is here being converted into a plug-in connector, and the filling material is Chatterton's compound

In the illustration the compound is shown in use, filling a cavity in an old valve mount which has been adapted as a plug-in connector. The compound in this case is useful, as it binds the wires to the base, and, at the same time, is an excellent insulator. The semi-fluid compound is melted in and flows to the bottom of the hole. The compound can be used for any purpose where local insulation is needed, as, for example, when a conductor is recessed into a groove in the underside of a baseboard. The groove is filled after the wire is in place. The compound is also suitable for filling holes in ebonite panels that are no longer required or have been drilled in error.

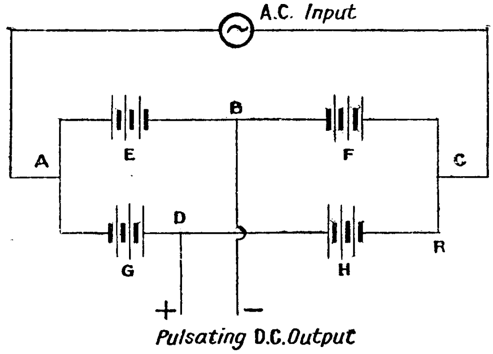
CHEMICAL RECTIFIER. Electrolytic device for changing alternating current to direct current. The action of the chemical rectifier depends upon the fact that with certain pairs of electrodes in an electrolyte the current passes much more freely in one direction than in another.

If plates of aluminium and carbon are placed in an electrolyte of a solution of alum, or dilute acids which yield oxygen on electrolysis, the current passes easily from the carbon to the aluminium, but not from the aluminium to the carbon. The action is the same if an aluminium electrode and an iron, tin, or lead one are used, dipping into a saturated solution of ammonium phosphate. The current passes from the iron to the aluminium, but not vice versa. The ammonium phosphate must be pure, the ordinary commercial phosphate not working anything like so efficiently.

The alternating electro-motive force applied to each cell should not exceed about 80 volts, so that for voltages above that amount two or more cells must be used. The cells may be simply made out of glass jam jars or wide-necked glass bottles, using 16g. aluminium, galvanized iron, or lead fuse wire, the wires dipping an inch or so only below the surface of the electrolyte. The iron wire of one cell is joined to the aluminium of the next, and so on, by short brass connectors to allow the wires to be renewed when required. The aluminium wires are the positive electrodes and the galvanized iron wires the negative electrodes.

The figure shows how four units of such cells are used to convert the current. The alternating electro-motive force is applied at A and C and given out at B and D as direct current. It will be seen by the arrangement of the cells E, F, and G, H, that the output at B and D is constant in polarity, B being always negative and D always positive.

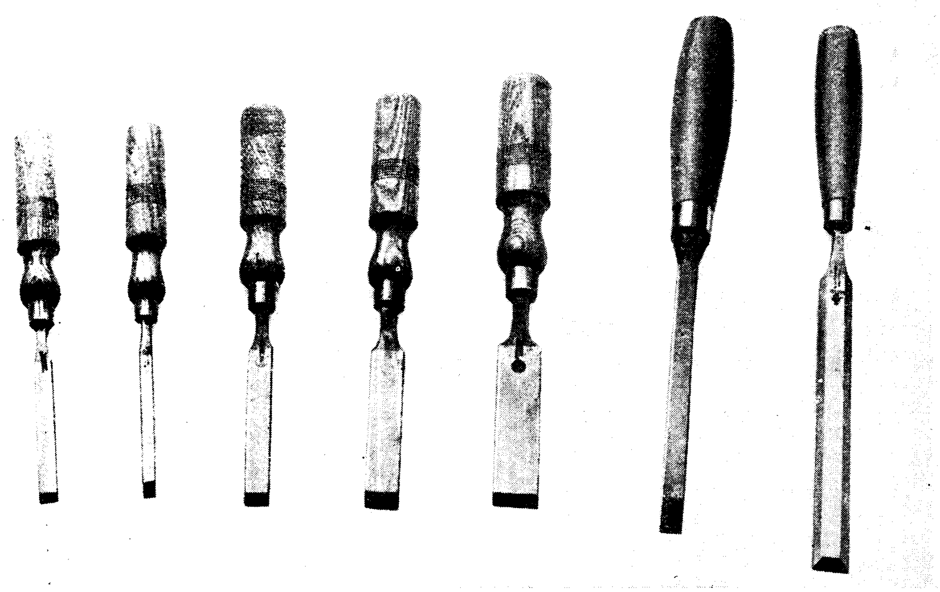
To change the pulsating direct current



CHEMICAL RECTIFIER CIRCUIT DIAGRAM

Alternating current can be changed to direct current by rectifying by the arrangement in this diagram

into a continuous uniform flow, the current is passed through a fixed condenser of about 3 mfd., through two choke coils of two to three henries inductance each, and finally through another condenser as the first.



SELECTION OF CHISELS USEFUL TO WIRELESS EXPERIMENTERS

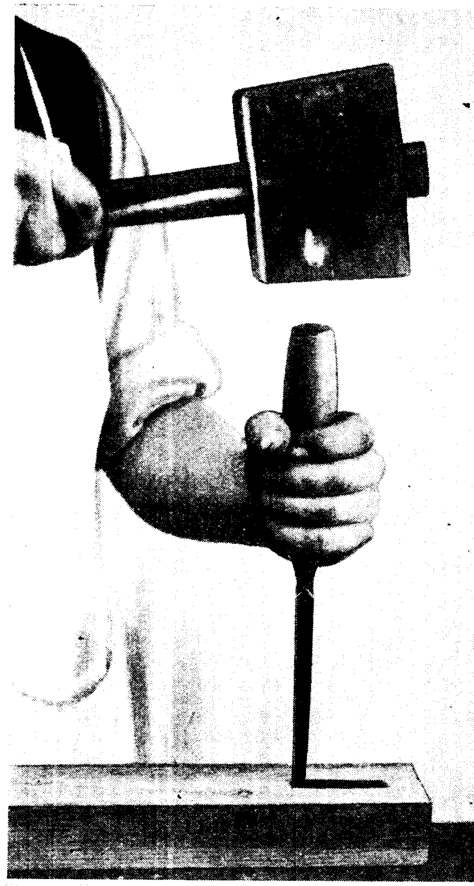
Fig. 1. Five handled-firmer type chisels are shown on the left. These are commonly used in many jobs which wireless experimenters do at home rather than send to cabinetmakers. The sixth from the left is a sash mortise chisel, frequently employed because of its extra strong blade, and the one on the right is a paring chisel

The transformed current is suitable for amateur transmission or for receiving amplifiers. *See* Accumulator; Nodon Valve; Rectifier; Tungar Rectifier.

CHISEL. A hand tool used in the cutting and shaping of wood. It is one of the most important of the woodworking tools for the experimenter, as, without it, it is impossible to do much constructive work.

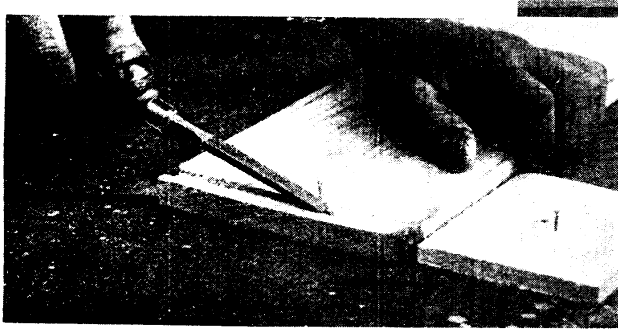
The ordinary type of chisel is known as a firmer chisel, and has a cast steel blade and a wooden handle. The amateur will do well to purchase the chisels ready handled, that is, with the handles fixed to the blades. They are then known as handled firmer chisels, and five of the most useful sizes are illustrated in Fig. 1 and also a mortise chisel and a paring chisel. The sash mortise chisel is much stronger in the blade than the others, as it is used to cut deep holes for mortises and similar work.

The paring chisels are used for cutting across the grain in a vertical direction, as for example, in cleaning up the sides of a deep hole, or in paring the end grain when making many types of joint. The handles shown on the last two are known as carver's handles, and are generally considered as being more suitable in use than the plain ash handles. A useful selection of chisels for the use of the wireless experimenter would comprise one each handled firmer chisels $\frac{1}{4}$, $\frac{3}{8}$, $\frac{5}{8}$, $\frac{3}{4}$, and 1 in. wide; one sash mortise chisel $\frac{1}{4}$ or $\frac{3}{8}$ in. wide, and a $\frac{3}{4}$ in. paring chisel.



USE OF A MORTISE CHISEL

Fig. 3. Cutting a mortise is a process requiring a chisel specially designed for that purpose. Here is a mortise chisel engaged and a wood mallet is used to drive it. A hammer should not be used



CHISELLING OUT A GROOVE

Fig. 2. Two saw cuts have been made as a preliminary operation before the chisel is engaged, and one hand only is used for chiselling out the groove

All chisels are used in practically the same way—by grasping the handle in the right hand and directing and guiding the blade with the left. The pressure to propel the tool is applied with the right hand, the left guides it, although, in fact, both the hands should work in unison and each do its share of the work.

In some cases the chisel is used in one hand only, as, for instance, when chiselling out the wood from a groove formed by making two saw cuts across it and removing the wood between them with the chisel. This is shown in progress in Fig. 2, and would be a suitable means of making the joint at the corner of a cabinet. In this example the wood is removed to the full depth of the groove from one side of the work only, and the wood turned around and the groove finished from the opposite edge. The object in doing this is to prevent the wood splintering at the edge when the point of the tool emerges.

The mortise chisel is used in conjunction with a mallet, and, as shown in Fig. 3, the chisel is held in a vertical position and driven downwards by the mallet. When cutting a mortise the wood is removed as far as possible with a brace and bit, and the remainder chopped out with the mortise chisel and finished with the paring chisel, which is propelled by hand. The fingers of the left hand should surround the bottom of the blade and control its direction. The right hand is used to press the chisel across the face of the wood and as it descends to cut off a thin chip, continuing until the hole is a perfect shape and fit.

All chisels should be kept perfectly keen by grinding the bevel from time to time and finishing by rubbing on an oilstone to produce the keen cutting edge. When not in use the chisels ought to be kept in a green baize or other case, as this keeps the cutting edges sharp and protects them from injury by contact with other objects. The system also saves the hands from cuts, which may easily occur if the chisels be left lying about the bench.

Golden rules in handling chisels or any other similar cutting tools are:—Always keep the hands behind the cutting edge, so that if the tool slips it will not cut the hands. Never leave chisels on the bench with the cutting edges outwards or over the edge of the bench, or a nasty cut will result. When there is any choice in the matter always chisel with the grain, that is, cut in the same direction as the grain of the wood. Work down hill, that is, along or down the grain. It is next to useless to attempt to cut uphill or against the grain, as the point of the tool will dig into the wood and the material be split and not cut cleanly. A good sharp chisel should remove the wood quickly and easily in the form of a crisp curly shaving and with a distinctive ripping noise.

CHLORIDE ACCUMULATOR. Trade name of a distinctive storage battery much used for heavy duties. The positive plate is formed of lead and pierced with a number of holes, each of which is filled with a coiled strip of pure lead. This is forced into the holes during the manufacturing process, and, it is claimed, gives the battery a capacity to successfully withstand heavy discharges without damage.

CHLORINE. One of the gaseous elements. Its chemical symbol is Cl, atomic weight 35·46, specific gravity 2·49 (air=1).

Chlorine is of little value in electrical work, but in combination with other elements it has many applications. Combined with hydrogen it forms hydrochloric acid. Ammonium chloride or ordinary sal-ammoniac is used as a soldering flux with zinc chloride. *See* Soldering.

CHOKE COIL. Choke coil is another name for an inductance, but with this distinction, an iron core is usually fitted, and no serious consideration is given to the effects of capacity.

The essential parts of a choke coil are two: (*a*) a core built up of laminations of soft iron, and (*b*) a continuous winding of insulated copper wire. The shape of the cross section of the core is not of material consideration, and may be round or rectangular. For use in wireless work the core is usually of the closed magnetic circuit type, *i.e.* it is in the form of a loop, with the windings wound on a bobbin placed on one limb of the loop. For laboratory work, a core of rectangular section and not of loop formation, but straight, is often used. It is usually capable of being pulled out of the winding at will, in order to vary the inductance.

In wireless work, however, it is usual to make chokes of a specific size for their own individual purpose, and therefore they are not made adjustable. The effect of magnetic hysteresis is a considerable factor in the design of chokes, for it has the effect of distorting the wave-form of the current passing through, and to reduce these losses to a minimum the core is provided either with an air-gap between itself and the windings or bobbin, or it may be split longitudinally and a gap placed between the separate halves.

The formula to be used when designing a choke for a specific number of henries inductance, and where the iron circuit is closed, is as follows:—

$$L = \frac{(1{\cdot}257 \times \mu \times A \times N^2 \times 10^8)}{l}$$

where

L = inductance in henries,
μ = permeability (varies from 1000 to 2000),
A = effective area of iron cross-section in square centimetres,
N = number of turns,
l = length of magnetic path in centimetres.

The effective area of cross section is the figure arrived at after allowing for air space, etc., between the core-lamination. This, in most cases, is somewhere in the region of 90 per cent of the total cross-sectional area. From the above formula it will be noticed that the inductance varies as the square of the number of turns, and as the area and permeability of the iron, but inversely as the length of the magnetic path. On account of the importance of the permeability of the iron and its effect with different current values, it is perhaps advisable to modify the formula given to obtain more accurate results.

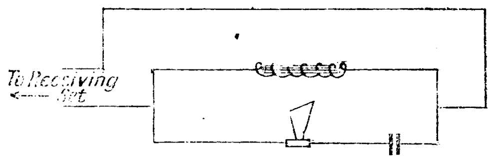
The permeability of a magnet or a piece of magnetic material is its ability to be magnetized when under magnetic influence. Bodies or materials are said to possess a high permeability when their receptive (not necessarily permanently receptive) power of magnetic influence is high. It will be seen that the effective magnetic inductance from a given current value in the core of a choke depends to a large extent upon the permeability of that core. In view of this the following modification of the formula given (which takes current into consideration) should be noted, viz.:

$$L = \frac{1.257 \times I \times N^2 \times A \times 10^{-8}}{l}$$

when L = inductance in henries,
I = current in amperes,
N = number of turns,
A = effective area of air gap in cm.,
l = length of air gap in cm.

The effect of a choke coil in an alternating current circuit is to impede the current. Choke coils are to be preferred to a resistance, because having themselves a low resistance, they do not waste current in heat. Should a choke having an adjustable coil be placed in series with a lamp in an A.C. circuit, and with the core withdrawn, the usual brilliancy of the lamp will result. If, however, the core is pushed inside the coil, the lamp will become dimmer as the core is pressed home.

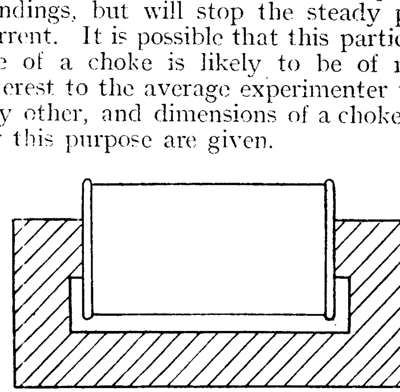
Again, a choke has the effect of damping out fluctuations in a circuit, and for that reason it is of great value in wireless work. For instance, a choke will have no effect of any consequence upon a steady valve-plate current, but will almost completely block speech-modulated currents. On the other hand, a condenser will not pass the steady plate current, but will offer no resistance to the modulated current. Thus it will be seen that by the use of these two instruments in conjunction, say, with a loud speaker, one may arrive at the ideal condition where the loud speaker has no comparatively large plate currents to deal with, but merely the modulated currents. In this manner the winding will be preserved from being burnt out, and yet full volume remains, for the plate current is not wanted in the loud speaker for sound production. Reference to Fig. 1 will show how this is accomplished.



CHOKE COIL AND LOUD SPEAKER

Fig. 1. Loud-speaker circuits are in some cases designed with a choke coil included, as here indicated. The object is the preservation of the loud-speaker windings from burning out

It will be seen from this arrangement that the choke will allow the steady plate current to get to the plate, but will stop the modulated current, while the condenser will allow the modulated current to pass through the loud-speaker windings, but will stop the steady plate current. It is possible that this particular use of a choke is likely to be of more interest to the average experimenter than any other, and dimensions of a choke coil for this purpose are given.

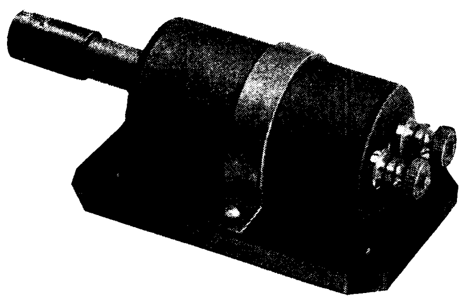


CLOSED-TYPE CHOKE COIL

Fig. 2. Closed choke coils of this kind are built up of rectangular laminations or lengths of soft iron wire

A core of the closed circuit type, Fig. 2, should be made, with an effective cross-sectional area of not less than ½ sq. in. The winding should consist of about 10 oz. of double silk-covered copper wire, wound carefully upon a shaped cardboard former. The core may be built up of stamped laminations of rectangular or serrated formation, or of soft iron wire laid in straight lengths, and finally, when the coil is in place, bent back upon it to meet end to end, in order to complete the magnetic circuit. The condenser used should be of about 4 to 5 mfd.

The construction of a small choke coil for use in many receiving circuits is not a difficult matter. The core is composed of a bundle of soft annealed iron wires bound together at the ends with very

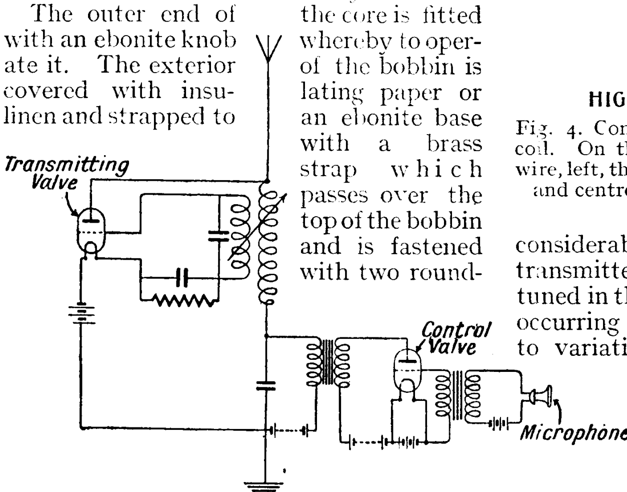


HOME-MADE CHOKE COIL

Fig. 3. Home-made choke coils can be constructed. A bobbin is wound with fine insulated wire, with a movable wire core sliding in or out. The handle is seen on the left of this example

fine wire. A hardwood or ebonite bobbin is turned to shape in the lathe and wound with fine well-insulated wire. The ends of the wire windings are taken to the end of the bobbin and terminate in ordinary brass terminals. The bore of the bobbin should be of such size that the wire core can slide in and out of it easily.

The outer end of the core is fitted with an ebonite knob whereby to operate it. The exterior of the bobbin is covered with insulating paper or linen and strapped to an ebonite base with a brass strap which passes over the top of the bobbin and is fastened with two round-headed brass screws tapped into the ebonite. Holes are drilled in the corners of the base for holding-down screws to attach the coil to the panel or other board.

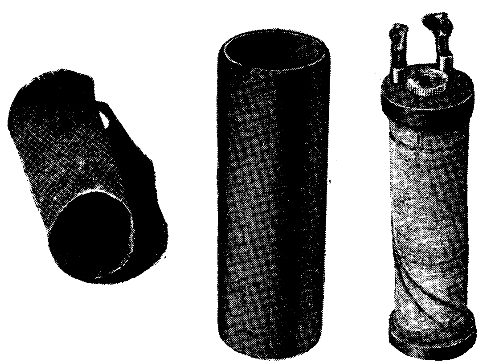


CHOKE CONTROL

Fig. 1. Transmitting apparatus in some cases, as in aircraft, for instance, uses the choke coil control as shown in this diagram, employing a control valve

The finished article is shown in Fig. 3. The components of a high-resistance iron core choke coil are shown in Fig. 4. This consists of a bobbin wound with very fine wire, terminating in soldering lugs. The core consists of a bundle of iron wires which fit closely into the bore of the bobbin. The windings, when finished, are covered with Empire cloth, and the whole forced into an iron case in the form of a tube.

CHOKE CONTROL. The application of the method commonly known as "choke-coil" control is chiefly used in connexion with valve transmitting sets for aircraft. To apply the electrical variations resulting from speech directed upon a microphone diaphragm, there are two methods employed. The first method is to connect the microphone directly in the aerial circuit. This, however, leads to

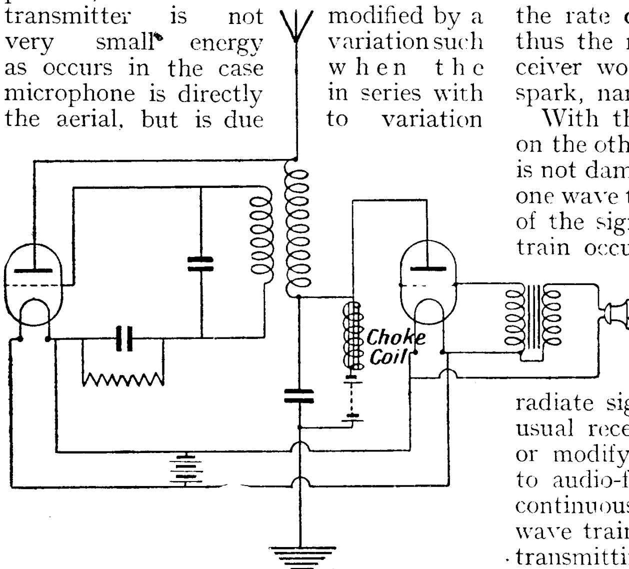


HIGH-RESISTANCE CHOKE COIL

Fig. 4. Components of a high-resistance choke coil. On the right is the core wound with fine wire, left, the Empire cloth with which it is wound, and centre, an iron tube which forms the case

considerable distortion of speech. The transmitter and receiver are very sharply tuned in this case, so that any slight change occurring in the resistance of the aerial due to variation of microphone resistance in series with it (such variation being due to the effect of speech setting up pulsations in the diaphragm) will cause considerable variations in the aerial damping, resulting in a considerable modification of the aerial output as well as some change of wave-length.

The second method consists of placing the microphone in shunt to a suitable condenser inserted in the aerial circuit. The variation in aerial output is then due to variations of charge on the condenser plates due to microphone currents. The use of a more practicable and less sharply tuned transmitter and receiver is then possible, in which the aerial current of the transmitter is not modified by a very small energy variation such as occurs in the case when the microphone is directly in series with the aerial, but is due to variation



CHOKE COIL CONTROL

Fig. 2. Between the control valve of this transmitter and the aerial will be seen a choke coil, which acts as a one-to-one transformer

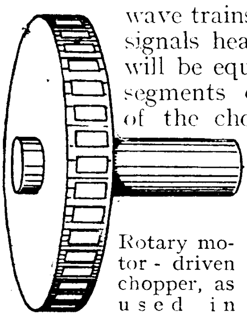
in aerial energy comparable in magnitude with the actual mean energy transmitted.

Before applying the microphone currents, however, a second valve is inserted to amplify them, as shown in diagram Fig. 1, and they can then be made comparable in magnitude with the actual aerial currents, so that the sensitiveness is very great without the necessity for very sharp tuning. It is found in practice that not only does the control valve increase the microphone currents, but it actually contributes to the aerial output. It is a simple step to arrange for the plate circuit of two valves to be supplied by a high-tension battery common to both ; similarly the filaments of both valves can be supplied by a single low-tension battery. In practice the transformer between the control valve and the aerial is replaced by a choke coil acting as a one-to-one transformer, hence the name " choke-coil control " (see Fig. 2).

CHOPPER. In the quenched spark form of transmitter, for each condenser discharge occurring once during each alternation of the secondary charging current, one wave train is radiated from the aerial. With current supplied at 500 cycles there would be, therefore, 1,000 wave trains radiated per second. At the receiver means are provided for recording this at the rate of one impulse per wave train, thus the note heard in the telephone receiver would be that of the transmitter spark, namely 1,000 per second.

With the continuous wave transmitter, on the other hand, the current in the aerial is not damped out to zero, and there is only one wave train radiated for each depression of the signalling key. The waves in this train occur, therefore, at radio-frequency, and would be inaudible in a receiver designed for reception of quenched spark signals. Accordingly to make an undamped wave transmitter radiate signals which are audible on the usual receiver, it is necessary to reduce or modify the radio wave-train frequency to audio-frequency by breaking up the continuous wave into groups or isolated wave trains. This is accomplished at the transmitting end by an instrument in the aerial circuit, termed a chopper.

It is a device similar to a commutator on an ordinary electromotor or generator, in other words, it is a rotating " make-and-break " switch. The frequency of the wave trains, and hence of the signals heard at the receiver, will be equal to the number of segments on the commutator of the chopper multiplied by the number of times it is revolving per second. The conditions are usually designed to give 1,000 interruptions per second. With transmitting sets of large power, the flashing over between segments and collector brushes renders its use impracticable, but for low-power sets it is satisfactory. The same results may be obtained by inserting the chopper at the receiving end of the system for breaking up the wave train.



Rotary motor-driven chopper, as used in interrupted continuous wave telegraphy

The figure shows an ordinary motor-driven rotary chopper, designed for I.C.W. telegraphy.

CIRCUIT BREAKER. Term used to describe a number of different pieces of apparatus having the same essential purpose of quickly severing an electrical circuit. Automatic circuit breakers are often known as automatic cut-outs, and are described under that heading in this Encyclopedia. A fuse is another type of automatic circuit breaker, as it severs the circuit when the current reaches a predetermined amount, the excess causing the fuse wire to burn, so breaking the circuit and cutting off the current. In power-station work a circuit breaker is the name given to a large switch. *See* Switch.

CIRCUITS FOR TRANSMISSION AND RECEPTION

Fundamental Principles of the Chief Types Explained and Illustrated

Without going into unnecessary detail concerning standard and special varieties of circuits, all of which are fully described, with constructional details, under their own headings, this contribution deals with the principles underlying the design of circuits for transmission and reception. See the individual circuits, e.g. Amplifier; Anode; Armstrong; Cockaday; Crystal Receiver; Flewelling, etc.

The difficulty of dealing with a subject under so comprehensive a title is not so much in making it representative, as in omitting all unnecessary complications and refinements, since the number of practicable circuits is very extensive indeed and many belong to the "freak" variety.

There are two general systems of radio transmission and reception, the continuous wave system and the spark system, sometimes referred to as "undamped" and "damped" systems respectively. Continuous oscillations or waves are generated by various means, the chief of which are radio-frequency alternators, direct-current arc generators, valve oscillators, and overlapping trains of damped waves.

Damped Wave Transmission

Discontinuous or damped oscillations are produced by the charging and discharging of condensers through a circuit containing an inductance. Audible response in the telephone is obtained at the receiving end, in the case of the damped or "quenched spark" systems, by rectifying the incoming waves with a detector or valve connected in series with the telephone. If an oscillating electro-motive force is then impressed upon this circuit from the wave trains, one half of the incoming wave cycles pass the rectifier, while the other half are practically suppressed; so that for each group of oscillations received from some distant aerial, a group of decaying direct-current pulsations occurs in the telephone circuit which stresses the diaphragm at audio-frequency and gives rise to audible sound.

Each wave train communicates a number of impulses to the telephone circuit of varying intensity, the average effect of which is much the same as that which would result from a single impulse per wave train, which accounts for the ability for the telephone to respond to the signal, since radio-frequency waves arrive at the rate of 500,000 to 1,000,000 cycles per second, which is far too high a rate for either the telephone diaphragm to respond to, or the human ear to distinguish.

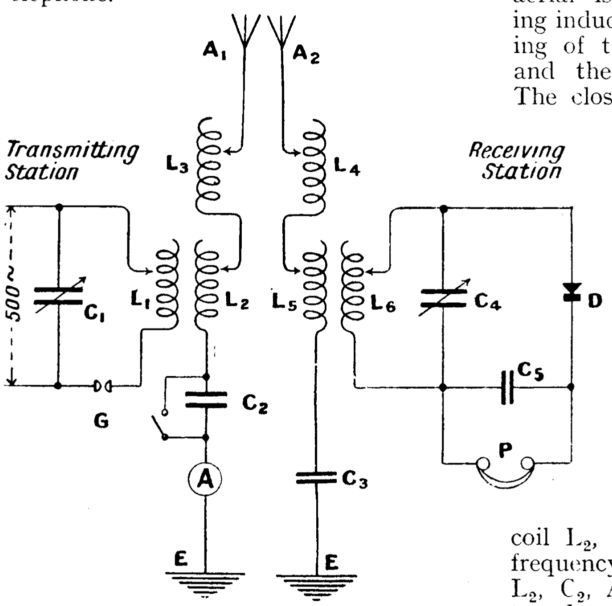
The radio-frequency waves, however, are transmitted in groups, each group corresponding to one spark or discharge at the condenser, and as these discharges occur at the rate of 120 to 1,000 per second, and each group of waves, due to a spark, impulsing the telephone as one wave only, the transition from radio- to audio-frequency is explained.

When the transmission system is conducted on the continuous wave method, the radio-frequency oscillations have to be converted into audio-frequency currents by other means. One is to insert first a rectifier in the receiving circuit which passes only waves arriving in one direction, so that the signal becomes a unidirectional but pulsating current, but still of too high a frequency for audibility.

Continuous Wave Transmission

The second stage is to break up the continuous train of rectified waves by a mechanical circuit interrupter known as a "tikker," which is usually a simple rotary make-and-break switch interrupting the wave train at the rate of 200 to 1,000 times a minute, and producing for each such group one impulse in the telephone diaphragm, so effecting the change to audio-frequency on much the same lines as with the spark system of transmission.

Another device is that of the slipping contact detector, by which periodic changes are made in some part of the receiving circuit resistance, so modulating the strength of the signals within the range of audibility. A further method for producing audio-frequency currents from continuous wave oscillations at radio-frequency consists of a means for giving rise to "beat" currents. It is accomplished by giving to the receiving circuit another set of impulses at a slightly different frequency from the transmitting frequency, when the periodic interference between the two results in a beat or third current at a lower rate than either, and which will depend upon the comparative frequencies of the two initial impulses. The beat current resulting from this will, if rectified, give audible signals to the telephone.



SPARK TRANSMISSION AND RECEPTION

Fig. 1. On the left is a spark transmitter circuit, and on the right a receiving circuit. These comprise a typical example of the complete radio-frequency circuits of a wireless system

Speaking generally, the continuous wave transmitting system calls for a much more expensive equipment than the spark system, which, for small power stations and portable sets, is a relatively inexpensive outfit. In radio transmission and reception each set contains two fundamental circuits, the open circuit, including all apparatus lying between the aerial and the earth connexion, and the closed circuit, including the telephone, detector, amplifier, etc., in the case of receiving sets, or the inductance, capacity, spark gap, and generator in the case of transmission.

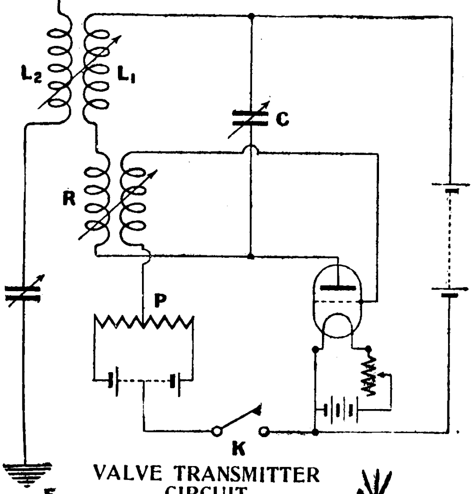
A typical diagram of the complete radio-frequency circuits of a transmitting and receiving station in a wireless system will be found in Fig. 1. The closed-oscillation circuit of the transmitter is represented by the condenser, C_1, the primary coil of the oscillation transformer at L_1, and the spark gap at G. The aerial or secondary circuit of the transmitting end comprises the aerial itself, A_1, the secondary coil of the transformer, L_2, the aerial loading inductance, L_3, the short wave condenser, C_2, and the aerial ammeter, A.

Turning to the receiving station, the aerial is shown at A_2, the aerial loading inductance at L_4, the primary winding of the receiving transformer at L_5, and the short wave condenser at C_3. The closed circuit on the receiving side comprises the secondary coil, L_6, the variable shunt condenser, C_4, the rectifier, D, the telephone, P, and the telephone shunt condenser, C_5.

When the condenser, C_1, of the transmitting station is charged at about 1,000 times per second from a 500-cycle alternator and transformer, 1,000 sparks per second discharge across the gap, G, and 1,000 groups of radio-frequency oscillations are emitted in the closed circuit, C_1, L_1, G. Coil L_1 then acts inductively upon coil L_2, and groups of waves of similar frequency flow in the aerial circuit A_1, L_3, L_2, C_2, A, E, if this circuit is properly tuned to resonance.

As the transmitter aerial oscillates it radiates an electro-magnetic wave motion which acts upon the receiving aerial circuit A_2, L_4, L_5, C_3, E, which also must be carefully tuned to resonance with the transmitter. The coil, L_5, then acts inductively upon L_6, the circuit L_6, C_4 being tuned to resonance by means of the condenser, C_4. Oscillations at the transmitted frequency flow in this closed circuit, where they are rectified by a detector, D, and made audible in the telephone, P. This diagram is representative of systems using damped wave transmission.

Four circuits require tuning, namely, the closed and open circuits of the transmitter, and the closed and open circuits of the receiver, all requiring tuning to the same frequency of oscillation. For continuous wave transmission by means of valves a very similar valve is used to that employed for reception, but with enlarged parts. It generates continuous high-frequency oscillations, which are used to emit radiations from the aerial.



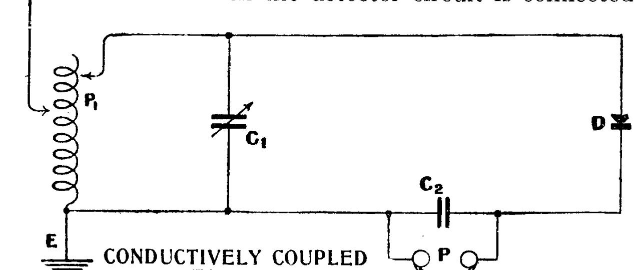
VALVE TRANSMITTER CIRCUIT

Fig. 2. An example of a transmitter circuit, including valve generator of continuous oscillations, is given in this diagram

Fig. 2 shows the circuit of a typical valve generator of continuous oscillations. The signalling key, K, is placed in the grid circuit, and on closing this a certain potential is applied between the grid and the filament, the value of which is determined by the position of the slider on the potentiometer, P. Variations in the plate current flowing through the inductance coil, L_1, R, are thus caused, which are sufficient to cause a small oscillation to start up in the circuit L_1, R C. The resulting current reacts by virtue of the induction of the magnetic field due to the coil, R, on the grid circuit causing a similar variation in the grid voltage, which can be given a considerable amplifying effect if the grid circuit happens to be tuned to the same frequency as the plate circuit. The coupling of R is adjusted so that just sufficient energy is fed in the grid circuit to keep the valve oscillating, and this action will continue so long as the key, K, remains depressed.

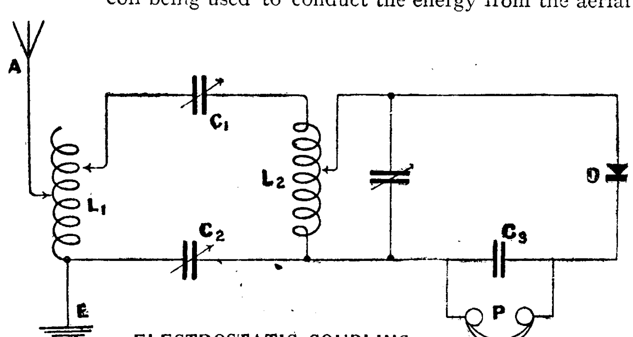
In order that the valve oscillations thus set up may be applied to the aerial for transmitting signals, it is only necessary to couple the aerial to the plate circuit (that is, where the energy is greatest) by means of an inductance coil shown at L_2, and to adjust so that the aerial and the plate circuit are in tune.

Receiving Circuits. These may be broadly classed into the following types: *Conductive,* where a single coil is used to conduct the energy from the aerial to the detector circuit; *Electrostatically Coupled,* where the aerial tuning coil is coupled to the detector circuit through condensers and there is no continuous electric circuit; *Inductive,* where the aerial energy is transmitted to the detector circuit through inductive coupling, and the *Open Oscillator,* in which the detector circuit is connected



CONDUCTIVELY COUPLED RECEIVER

Fig. 3. Conductive coupling is used in this circuit, the coil being used to conduct the energy from the aerial

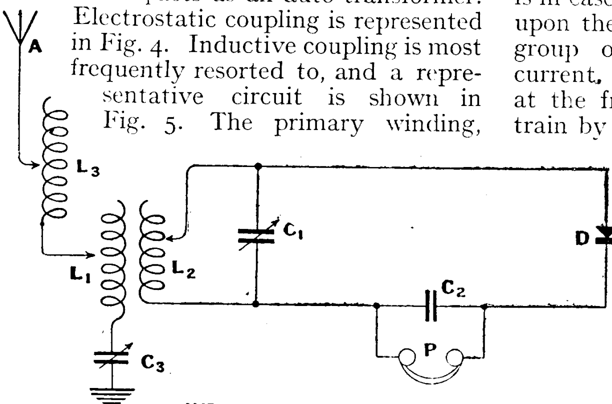


ELECTROSTATIC COUPLING

Fig. 4. In this circuit the aerial tuning coil is coupled to the detector circuit through condensers. There is no continuous electric circuit

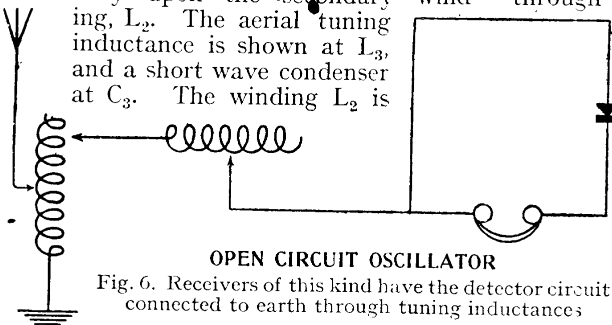
to earth through tuning inductances adjusted to the frequency of the incoming oscillations.

Conductive coupling is shown in Fig. 3, where coil P_1 acts as an auto-transformer. Electrostatic coupling is represented in Fig. 4. Inductive coupling is most frequently resorted to, and a representative circuit is shown in Fig. 5. The primary winding, L_1, of the receiving transformer acts inductively upon the secondary winding, L_2. The aerial tuning inductance is shown at L_3, and a short wave condenser at C_3. The winding L_2 is shunted by a condenser, C_1, of variable capacity, consisting of the usual arrangement of fixed and movable plates. The secondary circuit includes also the rectifier, D, a telephone, P, and a shunt condenser, C_2. Longer or shorter wave-lengths are allowed for by the aerial tuning inductance, L_1, L_3, an increase in the number of turns included by the slider corresponding to increased wave-lengths, and vice versa.



INDUCTIVE COUPLING

Fig. 5. Aerial energy in this case is transmitted through inductive coupling to the detector circuit



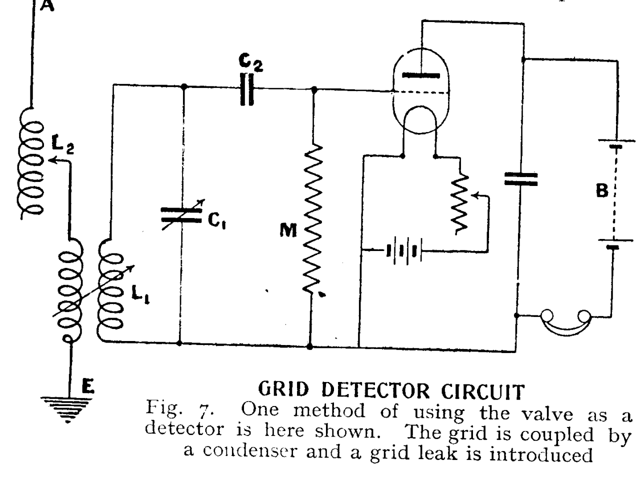
OPEN CIRCUIT OSCILLATOR

Fig. 6. Receivers of this kind have the detector circuit connected to earth through tuning inductances

If the wave-length of the transmitting station should be less than the natural wave-length of the receiving aerial, it can be tuned to resonance by the insertion of a condenser, C_3, in series with the aerial circuit. The open circuit secondary is shown in Fig. 6. Its particular advantage is in cases where the response is dependent upon the voltage impressed by any given group of oscillations rather than the current. Maximum potential is secured at the free end of L_2 for a given wave train by tuning the circuit L_1, L_2, D, P, to the frequency of the incoming waves. Response is secured in the same way as in systems having an entirely closed secondary circuit, but owing to the increased voltage applied to the detector stronger signals are obtained.

Up to this stage the means adopted of rectifying the waves has been the employment of the well-known crystal detector. The rectified current wave is in such cases stored in the telephone condenser and passed straight through the telephones. A valve, however, may be used instead of a crystal for rectifying and detecting, that is, making audible either the damped wave trains produced by a spark transmitter, or the beats due to imposing a second set of oscillations upon the waves received from a continuous wave transmitter.

When the valve is used thus as a detector, the small rectified charge on the grid is used to make a large change in the mean anode current by virtue of the valve characteristic curve explained

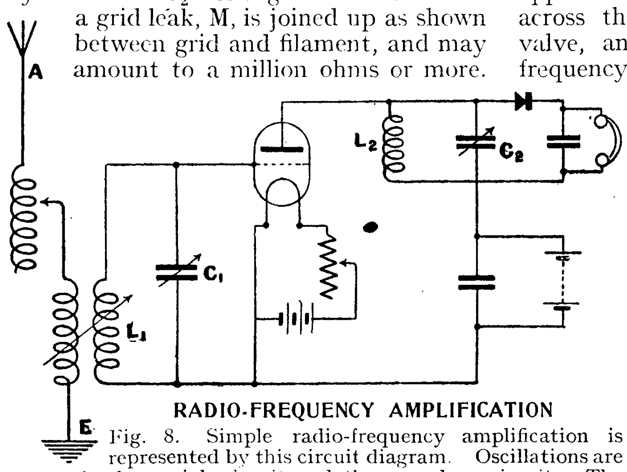


GRID DETECTOR CIRCUIT

Fig. 7. One method of using the valve as a detector is here shown. The grid is coupled by a condenser and a grid leak is introduced

elsewhere. The softer valves make the more sensitive detectors, since the bend in the characteristic curve is much sharper than in the case of hard valves. This gives the valve its "relaying" action, which is a more effective way of using the rectified wave.

Two methods of using the valve are possible, namely, grid detecting and anode detecting. Fig. 7 shows a circuit having the valve arranged as a grid detector. The secondary circuit, L_1, C_1, of the receiver is joined between the filament and the grid, the grid being insulated by condenser C_2. A high resistance called a grid leak, M, is joined up as shown between grid and filament, and may amount to a million ohms or more.



RADIO-FREQUENCY AMPLIFICATION

Fig. 8. Simple radio-frequency amplification is represented by this circuit diagram. Oscillations are set up in the aerial circuit and the secondary circuit. The radio-frequency waves being then imposed upon the grid of a valve, high-frequency changes take place in the anode current

Between the anode and the filament is the high-potential battery circuit, with the telephone in series with its negative lead, and shunted by a condenser.

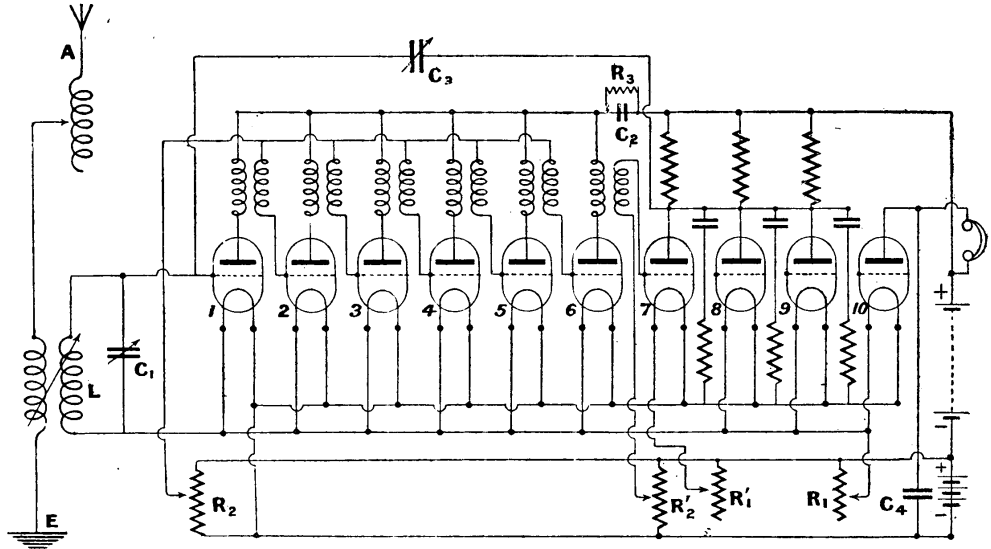
Before a wave strikes the aerial the grid potential will be the same as that of the filament and a steady current will be flowing from the battery through the valve and telephone corresponding to this potential. As soon as a damped wave train strikes the aerial an oscillating current will be set up in the secondary circuit, causing the grid-filament potential to be varied and the current flowing in and out of the grid itself to be varied. The gist of the operation is that oscillations of varying amplitude, on being applied between grid and filament, will result in the collection or rectification at the grid of a negative charge of varying amplitude.

This charge will bring about a fall in the mean value of valve and telephone current, and, consequently, the telephone diaphragm will oscillate in sympathy—one movement for each accumulation of negative charge on the grid, responding to the spark-train frequency of the transmitting circuit.

As an illustration of a simple and typical amplifying circuit may be cited the example shown in Fig. 8. This is a simple circuit suitable for high-frequency amplification. Its operation is as follows: The incoming radio-frequency wave sets up oscillations in the aerial circuit and in the interlinked secondary circuit L_1, C_1. Instead of this oscillatory circuit being applied to a crystal detector, it is applied across the grid and the filament of a valve, and consequently sets up high-frequency changes in the anode current. These high-frequency currents pass through the oscillatory circuit L_2, C_2 and maintain an amplified oscillation in it, provided that L_2, C_2 is tuned accurately to the natural frequency of circuit L_1, C_1 and the incoming waves. The oscillations can then be rectified by a crystal, and will result in audible sounds in the telephone.

A more elaborate system of amplifying, detecting, limiting, balancing, and note-magnifying appears in diagram Fig. 9. There are six valves, numbered 1–6, for high-frequency amplifying, one for detecting, limiting and balancing, and three for note-magnifying—in all, ten valves. The filaments of all valves, except that of No. 7, are joined in parallel, and their currents all controlled by the single rheostat, R_1. The steady potential of valve grids 1–6, inclusive, is under the control of the potentiometer, R_2, which is tapped off across the filament battery. The oscillating circuit L, C_1 is joined between grid and filament of No. 1 valve.

The amplifying group—namely, valves No. 1 to No. 6—are all coupled together by inter-valve air core transformers. No. 7 valve, which does duty as a detecting, limiting and balancing valve, is fitted with a separate filament rheostat, R'_1, and a separate grid potentiometer, R'_2, so that the best conditions for those various duties may be found by experiment. The last three valves, acting as note-magnifiers, are resistance-coupled. The resistance is



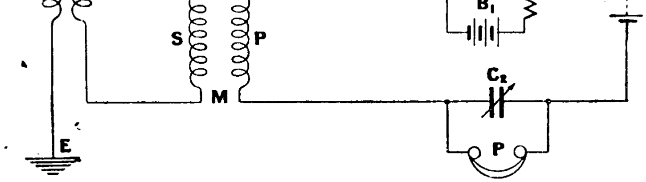
MULTI-STAGE AMPLIFYING CIRCUIT WITH RESISTANCE-COUPLED MAGNIFIERS

Fig. 9. Here ten valves are employed, six of which are for amplifying, one for detecting, limiting and balancing, and three for note-magnifying. All the high-frequency amplifying valves are coupled by inter-valve air core transformers. The detector valve has a separate rheostat. The condenser C_2 provides an adjustable capacity coupling between the oscillating and detecting circuits

provided so that there will be the same voltage drop in the anode supply to the first six valves as there is in the supply to the last three, which have series anode resistances.

The condenser C_1 provides an easy path for high-frequency currents, and prevents self-oscillation from being set up when it is not required. The condenser C_3 provides an adjustable capacity coupling between the anode of the detecting valve and the oscillating circuit, so that by a suitable adjustment the variations in anode current may be made to maintain self-oscillation in the circuit L, C_1 when this is required for the reception of continuous waves. The telephone is joined in series between the anode of the last valve and the high-potential battery, C_4 being the telephone condenser.

To illustrate the principles of regenerative circuits reference should be made to Fig. 10. It has been explained how the valve functions by changing the strength of its plate current when subjected to variations of grid potential by the action of the incoming oscillations, also how very slight changes in the grid potential act in producing relatively large changes by its relaying effect. That is to say, if the grid potential already existing is reinforced and raised above or below the maximum value by an incoming radio signal, a still greater change in the telephone current is bound to follow.



SIMPLE FORM OF ARMSTRONG CIRCUIT

Fig. 10. Regeneration takes place when this circuit is employed. The system upon which the apparatus works is due to Major Armstrong, who, by impressing upon the grid circuit the radio-frequency component of the plate current to synchronize with the incoming signals, increased the latter considerably

Since during the reception of radio signals the plate current varies as the frequency of the incoming oscillations, it will be evident that if the radio-frequency component of the plate current can be impressed upon the grid circuit to synchronize with the incoming signals, the energy of the original signal will be largely increased; in other words, regeneration will be the result. This system, which is due to Major Armstrong, is shown in a simple form in Fig. 10.

It will be seen that the plate or output circuit of the valve is coupled to its grid or input circuit through a radio-frequency transformer, M, having primary and secondary windings, P and S respectively. A very small amount of the energy supplied to the grid circuit will release a considerably greater amount of energy on the plate circuit. Part of the energy so liberated in the plate circuit is in turn impressed upon the grid circuit again through the coupling transformer, and the differences between maximum and minimum potentials between the grid and filament increased accordingly. Increased energy is then liberated in the plate circuit, but obviously the regenerative process cannot continue indefinitely, and the final amplitude of the regenerated current is governed by the electronic emission due to the temperature of the valve filament.

Many variations of regenerative and so-called super-regenerative circuits have been devised, such as audio-frequency regenerative circuits and combined radio- and audio-frequency regeneration, etc. Generally speaking, beside the manifold amplification these circuits permit of the present advantages of increased selectivity due to the following facts. Normally, the incoming signal would be highly damped, consisting of but a few oscillations per wave train; the additional energy liberated by the plate circuit through the reaction system of coupling actually increases the number of oscillations per group, and the circuit acts, therefore, as one in which the damping has been somewhat reduced, hence it permits better discrimination between signals of different wave-length or frequency.

CIRCUIT TESTER. General term for a number of devices used to test the continuity of a circuit or its insulation value. One simple arrangement is a small electric flash-lamp bulb attached to one pole of a small battery. Leads are taken from the lamp and the other pole of the battery to the part to be tested. If the circuit is complete the lamp will light unless the resistance of the circuit be very high, when additional battery power will be needed to overcome it. *See* Bulb Holder; Galvanometer; Megger.

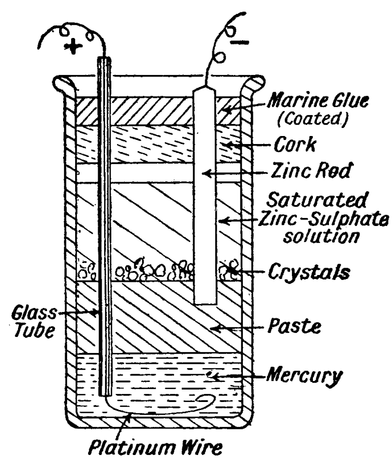
CIRCULAR MIL. Name given to the area of a circle having a diameter of one mil. The latter is one-thousandth of an inch. *See* Mil.

Cl. Chemical abbreviation for the gaseous element chlorine (*q.v.*).

CLARK CELL. One of the primary cells. The Clark cell is designed to generate an absolutely reliable and constant E.M.F., irrespective of all local conditions. The only thing affecting the E.M.F. is temperature. At a temperature of 15° C. its E.M.F. is 1·434 volts. To calculate its E.M.F. at t degrees C., the following formula applies:

$$\text{E.M.F.} = 1{\cdot}434\{1 - {\cdot}00077\,(t - 15)\}\text{volts.}$$

In its usual form the cell shown in the figure consists of an outer container of glass, similar to a test tube, of 2 cm. in diameter and 5 cm. deep. A layer of



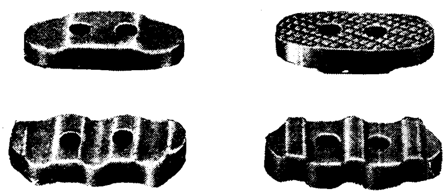
COMPOSITION OF A CLARK CELL

Constant electro-motive force is generated by a Clark cell, the composition of which is shown diagrammatically. The cell is used for standard tests

mercury is placed at the bottom, and forms the positive element. Immediately above the mercury is a thick paste consisting of mercurous sulphate and saturated zinc sulphate solution. Above the paste is placed the saturated zinc sulphate solution containing crystals.

The negative element is a zinc rod pushed well down into the paste. A tight-fitting cork serves to keep this in position. Provision is made to keep contact with the mercury by means of a platinum wire shielded from the upper ingredients by a glass tube. The uppermost part of the test tube is sealed with marine glue coated with sodium silicate. The Clark cell is adopted by the Board of Trade for standard test work.

CLEAT. Fasteners used to attach a conductor to a wall or other support. As commonly used they take the forms illustrated, and comprise a pair of porcelain clips, one acting as the base, the other as



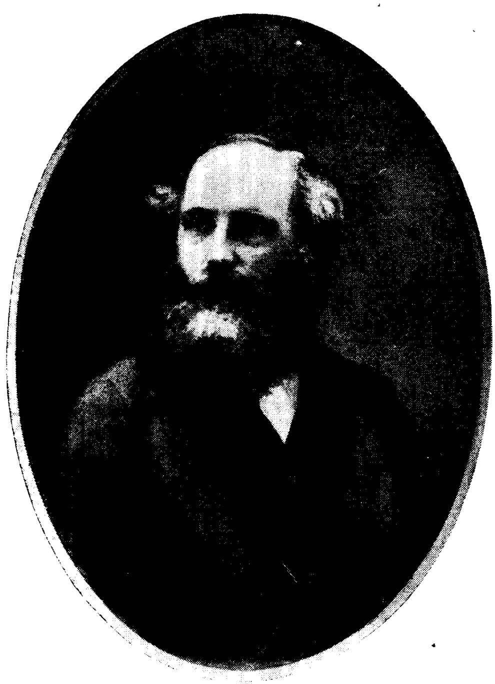
CLEAT FASTENERS

Porcelain cleats are used for fastening wires or other wireless components because of their insulating properties

the clip. They both have grooves in them, and the wires are laid therein, the clip placed in position, and secured with a screw or screws. They are useful to the experimenter for leading-in wires and for conductors for battery charging or other purposes when it is desired to bring a conductor into a building and to insulate it from the wall or other point of support.

CLERK-MAXWELL, JAMES. Born at Edinburgh, November 13th, 1831, and educated at Edinburgh and Cambridge Universities, he became Professor of Natural Philosophy at Aberdeen, 1856-60, and Professor of Physics and Astronomy at King's College, London, 1860-65. In 1871 he became the first holder of the new chair of experimental physics at Cambridge, where he died, November 5th, 1879.

Clerk-Maxwell was recognized in his later years as one of the greatest authorities on pure physics of his time, and his fame has been steadily increasing since his death. Wireless owes Clerk-Maxwell a deeper debt than any other man. Electricity was the chief study of his lifetime, and his first important paper on the theory of electro-magnetism was communicated to the Royal Society in 1867. In 1873 he published his "Electricity and Magnetism," a work on the subject which has never been surpassed. In it he formulated his famous electro-magnetic theory of light and his theories on electric



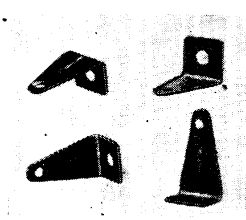
JAMES CLERK-MAXWELL

Modern wireless science and the theory of electric waves were developed from the results of the life-work of this great scientist. From a portrait in the National Portrait Gallery

Photo, Emery Walker

waves which developed into the modern system of wireless telegraphy and telephony through the experiments of Hertz.

CLIP. Device used to support one part of a piece of apparatus to another. The simple examples given in Fig. 1 show useful clips for the experimenter. They can be purchased at small cost or made from thin brass strips, and have many uses, as illustrated in Fig. 2.



METAL CLIPS

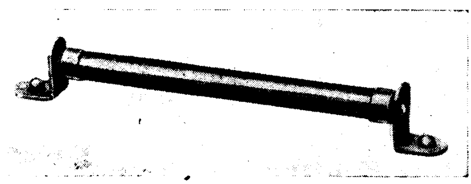
Fig. 1. Metal clips are used in wireless for many purposes where contact is permissible

These clips are sufficiently springy to permit the resistance being pulled out and replaced by another, and effect contact between the end caps of the resistance and the conductor wire attached to the underside of the clips.

Another type is shown in Fig. 3, and is a patent clip which is very handy for the experimenter. The example illustrated is fitted to the base of an Igranic coil holder and in use the clip is depressed, the conductor wire passed through the hole in the upright post, and held there by the resilience of the clip. This is shown at the right of Fig. 3, where a conductor is shown in position and the other clips in the raised position which they normally occupy when a wire is not being held. Numerous other types of clip are made and used on wireless work, but most of them have distinguishing names and are dealt with under those titles in this work. *See* Connectors ; Fahrnstock Clip.

TRANSFORMER COIL CLIPS

Fig. 3. Certain patterns of transformer coil holders use clips to hold the lead wires in position. An Igranic Electric Co. transformer is partly seen above, showing a platform on which the clips holding the wires are mounted



GRID LEAK CLIP

Fig. 2. Grid leaks are in many cases held in position by clips, which also form a means of contact, as in the case above

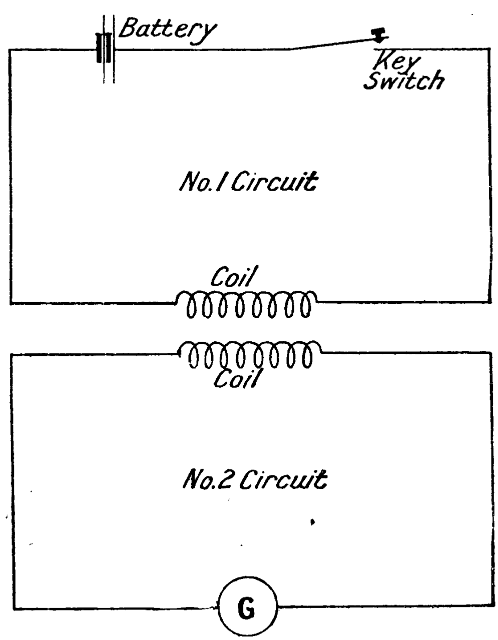
CLOISON. Used as an electrical term, indicates a flat coil of wire, which is a section of a complete coil. The best example of this method of coil construction is found in the larger types of induction coils. A number of cloison coils are used as the secondary winding instead of the continuous multi-layer method of winding. The end of one cloison is attached to the beginning of the next, and so on until the available space is completely filled. The advantage of this type of coil building is very great. In the event of an insulation breakdown the faulty cloison can be easily found and either entirely disconnected or replaced with another. In the layer type it would probably be necessary to rewire the secondary coil entirely in the event of a breakdown.

Cloison-built coils are increasingly used in plug-in tuning coils, as they have a low self-capacity.

CLOSE COUPLING. Close coupling is the term used in wireless work to denote the disposition of two or more coils in such a relationship to one another that their magnetic fields interact closely.

Any conductor carrying a current is surrounded by a magnetic field, in precisely the same manner as a magnet. The presence of iron near a conductor is not necessary to cause this field, as is sometimes assumed ; it merely concentrates the lines of force and gives them directive ability.

In any coil of insulated wire we have merely a long conductor, but owing to the



CLOSE-COUPLING THEORY

Fig. 1. By depressing the key switch in circuit 1 the galvanometer needle in circuit 2 is deflected momentarily. Immediately the switch is opened again the needle is again deflected, but in the opposite direction to its first deflection

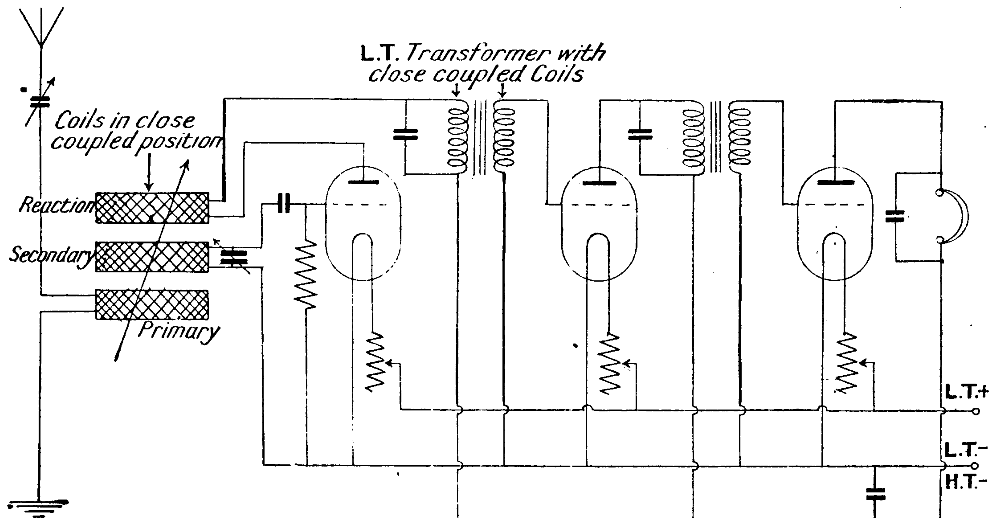
fact that this conductor is wound in coil formation in the same direction, a strong magnetic field is the result. In the case of a coil of flat formation, such as duo-lateral, honeycomb, pancake, and basket coils, this field is strongest at the flat sides; not around the rim or the inside. The tubular or solenoid coils, however, have their fields strongest in the interior.

Before going into the actual description and uses of close-coupled coils, a few words are necessary on induction. An induced current is only possible where changes of potential occur. Suppose a coil is connected, as in Fig. 1, to a battery and a key switch, and another coil not connected at all to the battery is placed adjacent to the first coil, the unconnected coil is joined to a galvanometer.

energy from one circuit to another by induction, it is imperative that the voltage, and therefore the current, in the energiser circuit should always be continually changing in value.

Alternating currents, oscillating currents (*i.e.* high-frequency alternating), and unidirectional pulsating currents all possess this character; their potential and current is never of the same value for any length of time, and it is for this reason that inductive coupling between two or more circuits can be used so extensively and with such excellent results in wireless work.

When any two coils are placed close together in such a way that they exert their greatest magnetic influence upon one another, they are said to be closely coupled.



CLOSE COUPLING OF THREE DUO-LATERAL COILS

Fig. 2. Variable coil coupling, as in this circuit, is commonly practised. A three-valve set is represented by the diagram, and the three coils are for primary, secondary, and reaction purposes. In the position shown the coils are said to be close-coupled

On pressing the key switch and thus completing the first circuit, a deflection of the galvanometer needle will indicate that a current is present in the second circuit. It will be found, however, that the needle immediately returns to zero, even though the key switch is still depressed. If the first circuit is now broken by releasing the key the galvanometer needle is again deflected, but this time in the opposite way, indicating that a current has again been generated in the second circuit. From this little experiment a very important rule may be drawn, namely, that in order to transfer electrical

The following are examples of the particular uses in wireless circuits of close inductive coupling:—

(*a*) Aerial primary to secondary.
(*b*) Aerial secondary to reaction.
(*c*) Reaction to high-frequency transformer.
(*d*) Reaction to anode coil in tuned anode circuits.
(*e*) High-frequency transformer primary to secondary.
(*f*) Low-frequency transformer primary to secondary.

It should be noted that in cases *a*, *b*, *c* and *d* provision is nearly always made for the tightness of the coupling to be varied at the will of the operator, except in some sets, particularly B.B.C. apparatus, where often the relative positions of the coils are fixed to prevent misuse, particularly of the reaction coil.

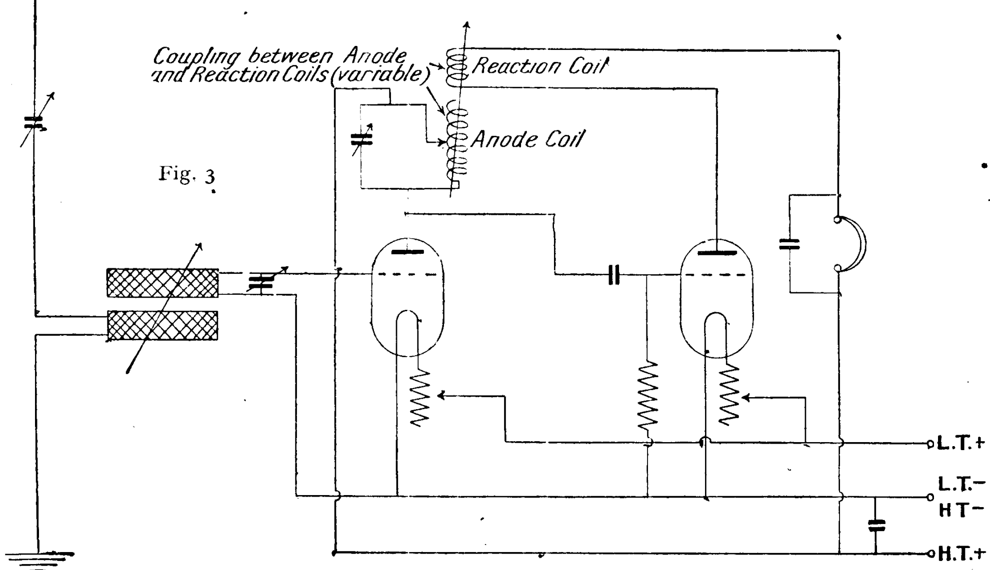
For obtaining efficient coupling between coils, they are mounted in coil holders designed for this purpose. In the case of the holder for two coils, one plug (into which the coil fits by means of a socket and plug) is stationary, while the other swings from a parallel position to the fixed plug to one at right angles to it. Thus the coupling can be varied within any limit required.

The principle of the three-coil holder is the same, the third plug occupying an exactly similar position on the other side of the fixed plug. Maximum closer coupling can be obtained by placing one coil over the other. The three-coil type is made particularly for use in tuners, where the three coils would be: (1) reaction, (2) aerial secondary, (3) aerial primary. A single-valve circuit with two note magnifiers using three coils in this manner is shown in Fig. 2. A set having a coil tuner of this type will give excellent results if honeycomb, duolateral, or some other type of low self-capacity coil be used. By varying the capacity, *i.e.* the distance between the coils, an unusual degree of selectivity may be obtained.

Placing the reaction coil next to the aerial coil (dispensing with the secondary coil) is a practice to be avoided on broadcast reception, for it is by this means that heterodyning, or howling in the aerial, is obtained, with very annoying results to other listeners-in in the vicinity. Furthermore, no increase in efficiency is obtained by this means, and a great deal of selectivity is lost.

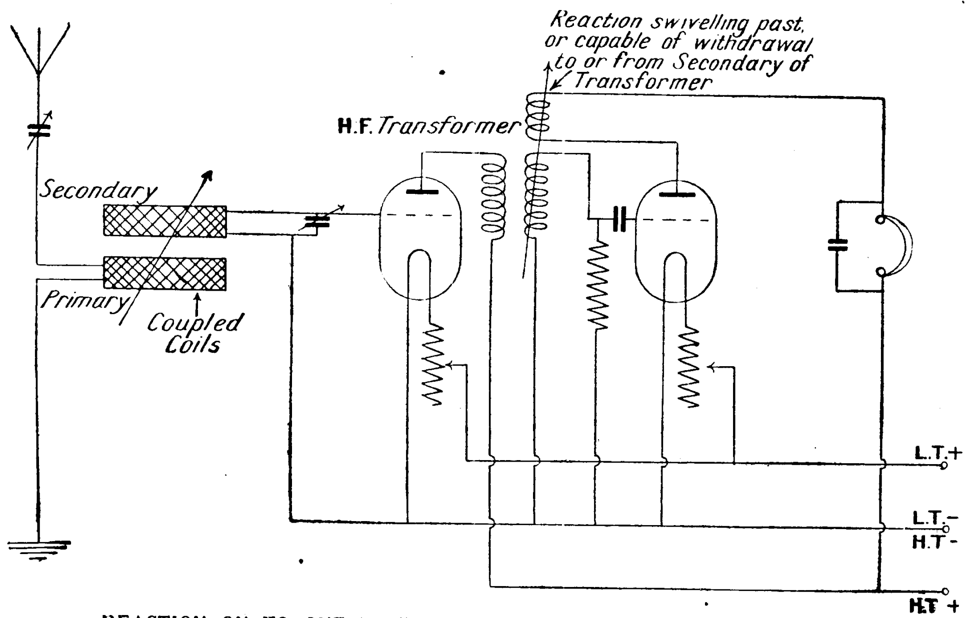
A method of close coupling the reaction coil to the anode in a tuned anode circuit is shown in Fig. 3. This is quite an efficient method of obtaining reaction, and is useful in that it will not re-radiate. It has, too, an advantage in that the anode coil is usually of a fairly large value (number of turns), which seems to allow a greater latitude in tuning.

Reaction on to one wiring of a high-frequency transformer is a favourite method with amateurs. Fig. 4 shows this method clearly. From experience with this method of reacting it would appear that the selectivity obtained is not nearly so good as with the other methods outlined. This method is, however, simple to make and operate, and perhaps appeals to the amateur for this reason. Further, it does not re-radiate. *See* Coil; Coupling.



CLOSE COUPLING THE REACTION COIL TO THE ANODE

Fig. 3. An efficient method of obtaining reaction is by close coupling the reaction coil to the tuned anode coil, as in the case of this two-valve receiver. In this circuit there are two instances of close coupling, the two duo-lateral coils also being in the close-coupled position



REACTION ON TO ONE WINDING OF HIGH-FREQUENCY TRANSFORMER

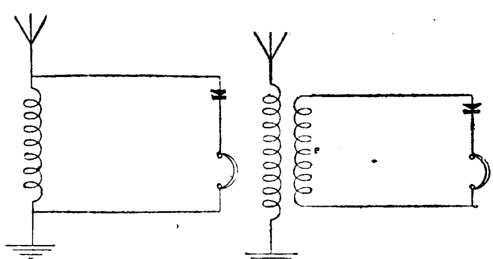
Fig. 4. High-frequency transformer coupling with reaction on to the secondary of the transformer is a method frequently used by amateur experimenters. The reaction coil is shown close-coupled, but it can be swivelled, or moved away, from the transformer in order to adjust reaction. The two duo-lateral coils which are shown close-coupled can also be spaced variably.

CLOSED CIRCUIT. A closed circuit as applied to a wireless set, either in transmitting or receiving, is one where electrical continuity is always established, so that the particular part of the set forming the closed circuit is not dependent upon aerial or earth to complete its continuity. It must be stated, while speaking of electrical continuity, that this does not necessarily imply a circuit complete to the path of a steady directional current. It does imply a circuit complete to oscillating currents of either high or low frequency. The insertion of a series condenser will not allow a closed circuit to pass a unidirectional current, but such a condenser may be introduced into an oscillating circuit without any detriment to its continuity.

The study of any valve circuit will reveal several instances of closed circuit. Possibly the most obvious is the circuit of the low-tension current, which includes the low-tension battery, filament resistance, and the valve filament. An example of closed circuit to oscillating currents includes high-tension battery, telephones, reaction coil, if any, anode via filament to negative side of high-tension battery. The grid circuit, again, forms a closed circuit, which can be traced through the tuning inductance and filament.

An open circuit refers usually to the primary tuning of a receiver where no direct coupling is made to a set, oscillations being transferred to the secondary or closed circuit by inductive coupling. The expression open circuit is often loosely used where an incomplete circuit is indicated.

Figs. 1 and 2 show respectively a closed and an open circuit in connexion with a crystal set. With regard to Fig. 2, the aerial tuning comprises the open circuit.



CLOSED AND OPEN CIRCUITS

Fig. 1 (left). In this case the circuit is closed. Fig. 2 (right). An open circuit is here shown. In Fig. 1 the closed circuit between aerial and earth is the same, but the crystal detector circuit is now coupled to it

The remainder of the circuit, comprising the crystal detector, telephones, and the inductance, B, form a closed circuit.

Referring again to the two circuits shown in Figs. 1 and 2, it will be found that the second illustration of the open and closed circuits combined has the advantage over the former in its superiority of increased selectivity. Its disadvantage lies in the increased difficulty of tuning.

CLOSED-COIL AERIAL. This is an alternative name for a frame aerial in which the ends are taken direct to the detecting panel. The aerial is in the form of a large coil. *See* Frame Aerial.

CLOSED-CORE TRANSFORMER. Expression used to describe a transformer wherein the magnetic circuit is completed metallically by the core, which protrudes beyond the windings. The primary and secondary windings are not of necessity wound over each other, but must be wound on a core that is common to both. The characteristic arrangement of the device is shown in the form of a diagram in Fig. 1. With such an arrangement, if the primary windings are less in number than the secondary and a source of alternating or oscillatory current be passed through it, the secondary voltage will be higher, and the transformer is known as a step-up transformer with closed core.

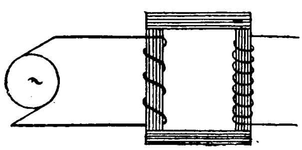


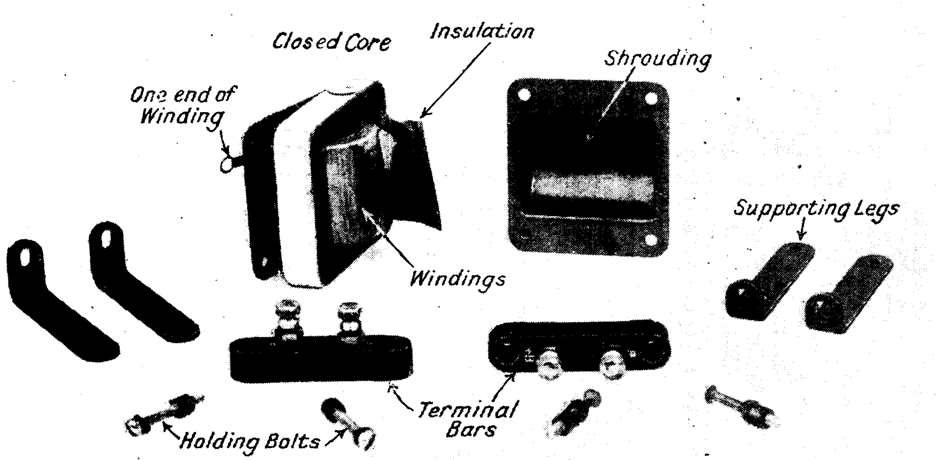
Fig. 1. Arrangement of a closed-core transformer as used for high-power work

When the primary has more turns in the winding than the secondary the apparatus becomes a closed-core step-down transformer.

Variations include a tapped primary winding, when the device is known as an auto-transformer. In all these types the iron core is used to concentrate the magnetic field, and the closed form is generally used for such purposes as the intervalve transformer between the valves of a detector and low-frequency amplifier.

An example of this class is shown in Fig. 2, where the core is visible, as the shrouding or cover has been removed and the windings partly exposed. In this example the two windings are superimposed and fully insulated from each other, and wound around a central member of the closed core, which is shaped roughly as a square and entirely surrounds the windings in a plane at right angles to them. The iron used in the cores of such transformers should be of good quality, or an alloy, such as Stalloy, with a low hysteresis loss.

There are several technical advantages with the arrangement of a closed core, the chief of which are the improved magnetic circuit and the possibility of reducing the size and weight of the device—a matter of importance with a portable set.



CLOSED-CORE TRANSFORMER FOR RECEIVING SET

Fig. 2. Parts of a closed-core transformer have been photographed in order to show method of building up, and also the several components. Note on the terminal bar, laid on its side, the marking which determines the purpose of the terminals

Closed-core transformers are extensively used on high-power work at generating stations in connexion with the transmission of wireless telegraphic and telephonic messages. *See* Transformer.

Co. Abbreviation for the name of the chemical element cobalt. It is also used sometimes as a contraction for complement.

COBALT. One of the metallic elements. Its chemical symbol is Co, atomic weight 59, specific gravity 8·32 to 8·95, and electrical conductivity 17, silver being taken as 100.

Cobalt is steel-grey in colour, resembling nickel, with which it is usually found associated. It may be used for nearly all the purposes nickel is, and, possessing greater strength would largely replace that metal if its manufacturing cost were not so high. Cobalt at present is used as an alloy of steel to produce high-speed steels.

THE COCKADAY CIRCUIT AND HOW TO USE IT

Principles and Construction of a Remarkable Receiving Instrument

This interesting circuit, which is of American origin, represents an important departure from ordinary practice. It is simple in construction and tuning, extraordinarily selective, and eliminates interference, and works well on any aerial, even when small and inefficient. The article on Bank-wound Coils should be read in conjunction with it. See also Circuits; Flewelling Circuit; Reflex Circuit

This is a well-known receiving circuit named after Lawrence M. Cockaday, its originator. It represents a radical departure from the ordinary circuit, regeneration being relied upon entirely for amplification. The rectifying valve is followed by two audio-frequency valves, which have in their circuit a condenser connected to a three-stud switch, which varies the music tone.

The manner in which broadcast and telephony can be handled by this tuner is remarkable. A set placed within two miles of 2 LO in London can receive any other broadcasting station in England while 2 LO is working.

The greatest peculiarity of the circuit is that the length, capacity, and other characteristics of the circuit to which it is connected are almost immaterial. For instance, if a set having this circuit is tuned to receive 2 LO on an aerial, say, 100 ft. long, and then, without being detuned, is connected to another aerial, say, 20 ft. long, 2 LO will always be in tune, despite the large difference in aerial lengths.

It will be seen from the theoretical wiring diagram in Fig. 1 and the photographs, Figs. 4, 5 and 6, of the interior of the set, that the coil L_1, a part of the primary aerial tuning arrangements, consists of one turn only of wire wound round a tunable and entirely closed circuit made up by a previously determined fixed inductance, L_2, tuned by a variable air condenser of 0·0005 mfd. capacity. The object in this design of extremely loose coupling is to secure absolute elimination of interference. The remainder of the primary aerial circuit comprises a tapped bank-wound inductance, L_3, arranged on the earth side of the aerial tuning system, and permits of coarse tuning in this circuit.

It will be seen that this form of inductive coupling allows a considerable step-up effect in the receiving transformer, which is as high as 65 to 1. The result of this is to secure a very high grid voltage even from a weak signal.

The receiving transformer consists of an entirely closed circuit, comprising a fixed inductance, L_2, and a variable condenser. This circuit is in the magnetic field of, and is therefore inductively coupled to, the grid circuit L_4 and C_2. It is in this manner that it acts as a stabilizer circuit, *i.e.* it keeps the circuit from oscillating due to some slight change in capacity or inductance.

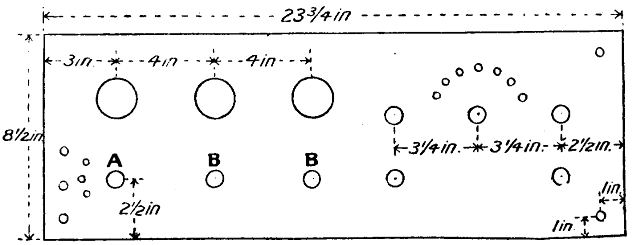
In the article on the Armstrong super-regenerative receiver it was shown that a valve will remain in a state of continued oscillation when the effective negative resistance of a circuit equals the positive resistance. This is done normally by varying the negative resistance upwards. In this set, however, the same result is obtained by varying the positive resistance downwards until the correct value is reached.

The remainder of the circuit follows standard practice, excepting the novel method of varying the tone of the set. This is effected by means of a fixed condenser, C_4, of 0·0005 mfd. capacity, in conjunction with a three-way switch. When the latter is placed in a central position the condenser is omitted from the circuit, and the wiring follows standard practice.

Placing the switch to the top stud results in connecting the grid of the valve to earth, thus by-passing a part of the oscillations, to secure a very mellow, though somewhat weaker, tone. The remaining contact arm position on the bottom stud connects the grid of the last valve to the anode circuit, where its presence is felt in a somewhat different tone.

The set as described in this article has a wave-length range of about 200 to 600 metres. Tuning, owing to extreme sharpness, is rather difficult at first. Vernier condensers are essential. If the filament control of the rectifier is not carefully handled when tuning, re-radiation is likely to occur. It is of paramount importance to carry out the instructions given in every particular. Otherwise the constructor may be very disappointed with the results. The parts required are :

Ebonite panel, $23\frac{3}{4}$ in. by $8\frac{1}{2}$ in. by $\frac{1}{4}$ in.
Ebonite panel, 11 in. by $1\frac{1}{4}$ in. by $\frac{1}{4}$ in.
1 23-plate condenser with $\frac{1}{8}$ in. spacing.
1 25-plate ,, ,, ,,
2 3-plate vernier condensers.
6 in. of $3\frac{1}{2}$ in., outside diameter, ebonite tube.
$\frac{3}{4}$ lb. No. 20 D.C.C. copper wire.
2 filament resistances (1 vernier type).
4 valve holders (flange type).
10 contact studs with 4 stops.
2 switch arms.
5 terminals.
1 0·00025 fixed condenser.
1 0·002 ,, ,,
1 2-megohm leak.
2 low-frequency transformers.
1 Dutch or other soft valve.
2 R valves or dull emitters.
12 in. of $\frac{1}{8}$ in. brass or copper wire.
$\frac{1}{2}$ lb. of No. 14 tinned wire for connexions.
Solder, fluxite, sheet brass, screws, nuts.
1 cabinet, or wood for same.



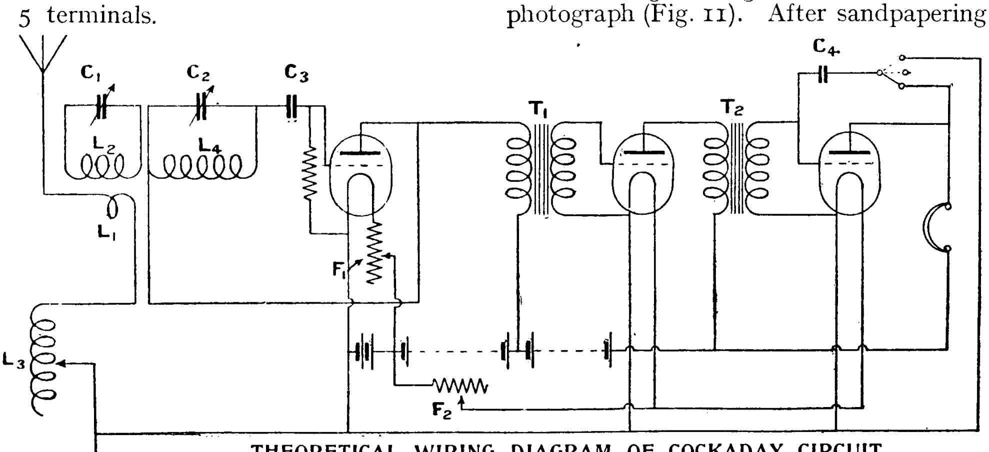
COCKADAY CIRCUIT PANEL

Fig. 2. Dimensions of the back of the panel designed for use with the Cockaday circuit are given above

Well-seasoned mahogany should be used for the cabinet, and cut to the following finished sizes :—

Bottom 24 in. by $8\frac{1}{2}$ in. by $\frac{1}{2}$ in.
Top $23\frac{1}{2}$ in. by $8\frac{1}{8}$ in. by $\frac{3}{8}$ in.
Sides (2) $8\frac{1}{8}$ in. by $8\frac{1}{8}$ in. by $\frac{3}{8}$ in.
Back (1) Fixed portion, $9\frac{3}{4}$ in. by $8\frac{1}{8}$ in. by $\frac{3}{8}$ in.
(2) Hinged portion, 13 in. by $8\frac{1}{8}$ in. by $\frac{3}{8}$ in.

The joints may be quite plain, screwed and glued together. Care must be exercised in fitting the hinges, as indicated in the photograph (Fig. 11). After sandpapering



THEORETICAL WIRING DIAGRAM OF COCKADAY CIRCUIT

Fig. 1. From the aerial lead will be seen a single turn of wire, forming part of the aerial tuning arrangement. This is wound round a tunable closed circuit with fixed inductance, L_2. By this very loose coupling interference is eliminated. L_3 is a tapped bank-wound inductance. The three-way switch and condenser C_4 form a novel means of varying tone. C_3 is a grid condenser

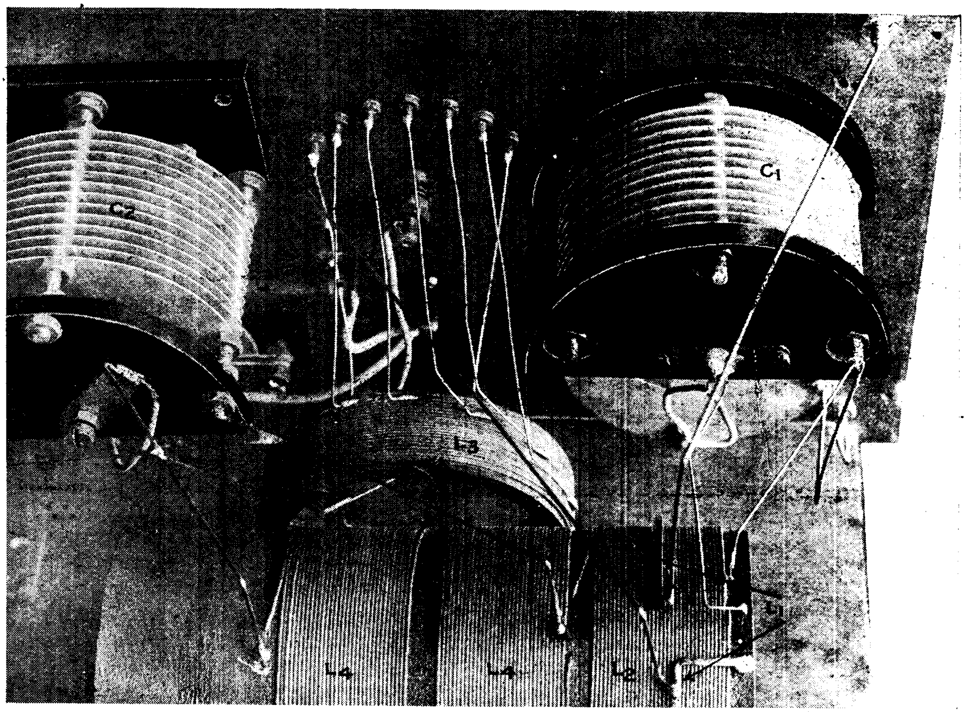


Fig. 3. Looking at the back of the instrument, the bank-wound aerial tuning inductance is seen at L_3 in the centre. C_1 and C_2 are reaction and grid capacity units, respectively. L_4 is the grid circuit inductance, and L_1 the single-turn aerial primary round the reaction stabilizer inductance L_2

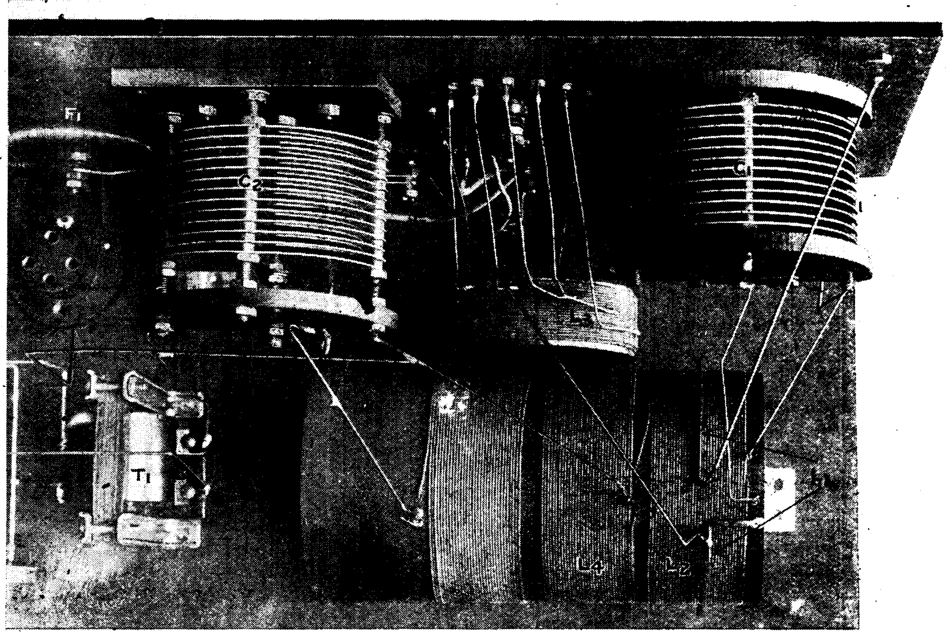


Fig. 4. On the left of this plan view is the first filament resistance, F_1, and the first L.F. transformer, T_1. The detector valve holder is also seen. Below the tuning switch is the grid condenser

BACK AND PLAN VIEWS OF THE COCKADAY RECEIVER down well, with worn paper, the cabinet should be dark-stained and french-polished.

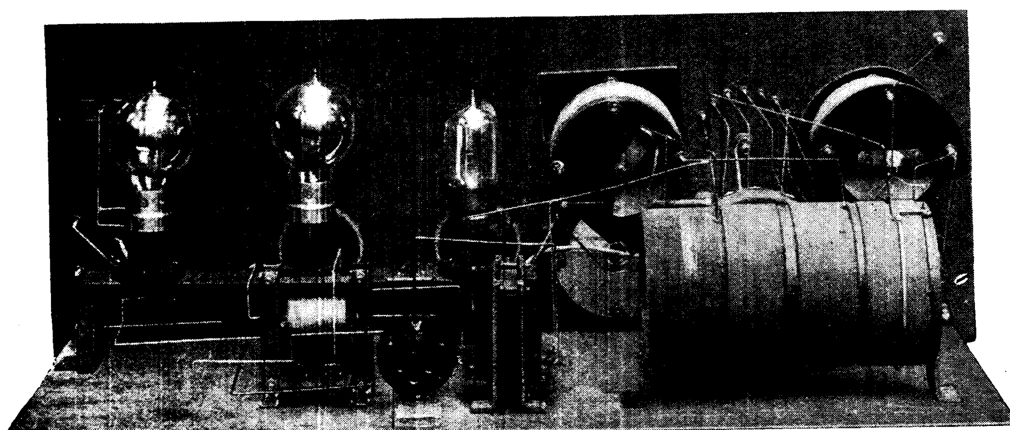
Good insulation is an important factor in this set, and good quality ebonite must be purchased. Buy the matt (sand-blasted) surface ebonite, if possible. If polished and tinfoil surface only be available, it is imperative that both sides should be matted by rubbing down with emery cloth. Grade F.F. is the best for the purpose. The panel should be cut and filed exactly square on all edges. When holding in the vice, its surface should be protected by placing a piece of wood on either side. Not only will this prevent the vice jaws from damaging the surface, but it will stiffen the ebonite and render the filing of the edges a much more simple job. Fig. 2 is a drawing of the panel from the back. All marking out must be done from that side. Pencil must not be used for marking out, for graphite is quite a fair conductor, and is difficult to remove from a matt surface.

Should the constructor have no facilities for drilling the large valve peep-holes, a number of smaller holes may be drilled instead in the form of a circle or cross. It is difficult to drill large holes in thin ebonite without cracking it, and a small hole should first be drilled and then opened out with a pin cutter.

After all holes have been drilled, any burrs which may remain are removed by a countersink. The holes for the wood screws may be countersunk so that the heads just come flush with the panel at the same time. After finishing the panel, the next step is the shelf or platform, upon which most of the components are assembled. A piece of $\frac{3}{8}$ in. mahogany is used for this purpose. It is cut about $23\frac{3}{4}$ in. long and $7\frac{3}{4}$ in. wide. It is fixed at right angles to the panel at the bottom and behind it, by three wood screws. As a considerable weight is imposed upon it, screws at least 1 in. long are necessary.

The condensers, switches, rheostats, fixed condensers and leak may now be fitted to the panel in the positions indicated in Figs. 3, 4, 5. The variable condensers shown are all home-constructed articles. It will be noticed that the verniers are of very simple construction. The fixed plates are mounted upon a strip of ebonite, just long enough to go right across the straight sides of the plates.

Attachment to the panel is effected by screws passing through these strips on to the panel. The moving plate is fixed to a shaft moving in a bush, the outside diameter of which is $\frac{3}{8}$ in. Contact to this plate is made by flex. Friction contact may be made, if desired, by attaching a flat phosphor-bronze spring to the panel, so that its free tip rests upon the end of the condenser spindle. If a vernier rheostat for the rectifier valve has been purchased, it must be fitted to the first filament rheostat hole from the left of the panel, looking from the front. If dull



ELEVATION VIEW OF REAR OF COCKADAY SET

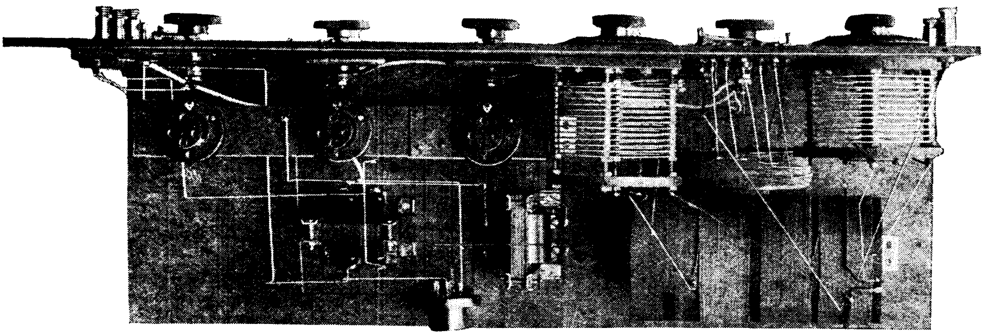
Fig. 5. Just visible between the condenser in the centre and its vernier is the grid leak. Note the right-angle position of the low-frequency transformers to prevent interaction by magnetic proximity. Between them is seen a valve holder, which acts as a socket for connexion to high and low-tension batteries, and replaces terminals for that purpose

emitter valves are to be used for the L.F. side a rheostat of high resistance should be purchased, for a 4-volt accumulator is used for the L.T. and the voltage has to be reduced to 1·8 for this purpose.

On the other hand, if R valves are to be used, a rheostat having an element able to stand the current of the two in parallel is necessary. The fixed condenser shown near the centre of the panel is the smaller one (0·00025 mfd.) and that near the telephone terminals the 0·002 mfd.

valve shelf, for different valves are of different heights. The object of the shelf is to bring the valves high enough to view their filaments.

The valve holders or pins should be fitted and wired up as shown in the photograph, Figs. 6 and 10. This must be done before the shelf is fitted to the platform, it being impossible to get at them afterwards. The fact that no battery terminals are fitted to the panel should be noted. The attachment of the battery



COCKADAY APPARATUS SEEN FROM ABOVE

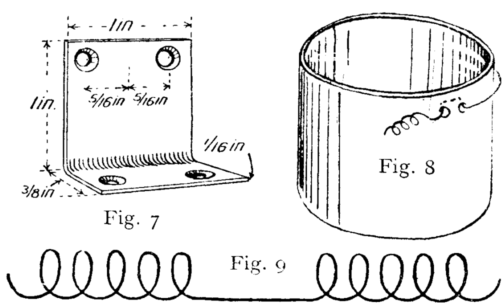
Fig. 6. Looking down upon the top of the Cockaday set, the arrangement of the components is clearly apparent. The wiring of the valve holder which connects the high- and low-tension batteries can be followed. Note also the relative position of the condensers and coils

The leak is fixed by two small brass angle brackets. It will be seen from the circuit diagram that the leak is connected from grid to earth, not across the condenser. Therefore the usual combined leak and condenser will be of no use in this set. The reason for this position is that it does not allow a steady positive current to adversely influence the operation of the grid of the first, or rectifying valve, as would result if the grid leak were placed across the grid condenser.

After all the panel components have been fixed, together with their knobs and dials, the platform should be fitted to the panel ready to receive its components.

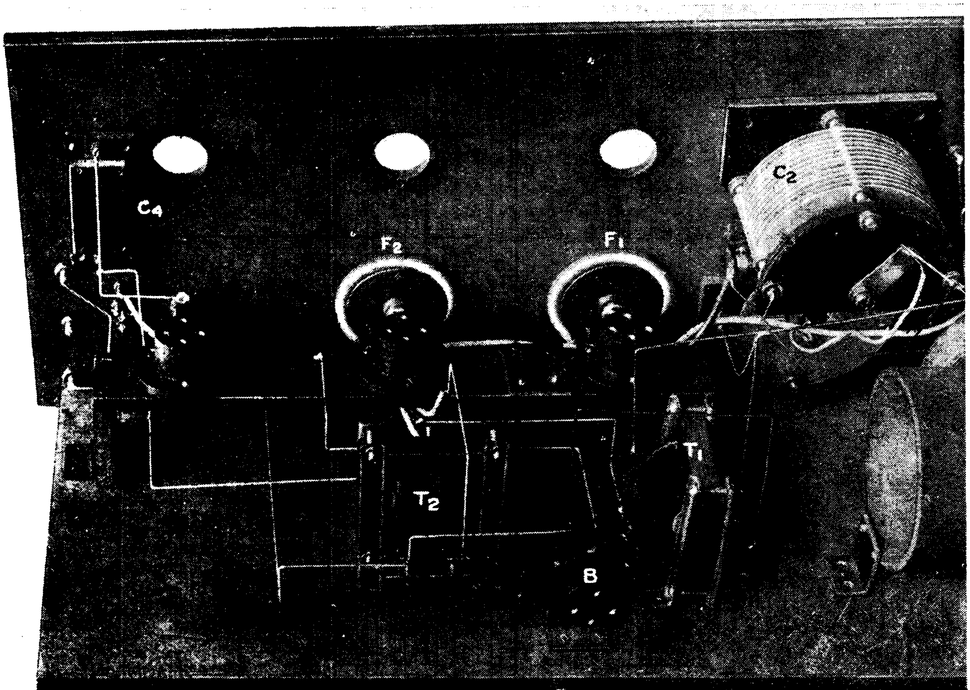
The next item for consideration is the shelf supporting the valve holders. The ebonite should be dealt with exactly as for the front panel, as surface leakage here would completely spoil the receiver. The use of valve holders or valve pins is quite optional. Valve holders are generally more convenient and take less time to fit, but are more expensive. The pins or holders are arranged so that the valves, when fitted, come in line with the peep-holes. It is inadvisable to give dimensions for the wooden blocks that support this

connexions to the back of the receiver facilitates the wiring considerably. Four battery connexions are necessary in this set, for there is a separate H.T. lead to the rectifier. For the sake of convenience and portability, a valve holder is used to provide the connexions. The removal of a four-pin plug from this is a simple method of entirely disconnecting batteries. This valve holder is fixed to the platform by a brass bracket, and is intended to be fitted right opposite the hole already made



CONSTRUCTIONAL DETAILS

Fig. 7. Bracket for fixing the coil former. Fig. 8. Former, showing holes for beginning and end of winding. Fig. 9. How the reaction stabilizer winding is divided



REAR VIEW OF COCKADAY DETECTOR AND AMPLIFIER

Fig. 10. Comparison with the wiring diagram will show the function of C_4, a 0·002 fixed condenser on the left. F_1 is the first filament resistance for the rectifying valve, F_2 the second filament resistance for both low-frequency valves, C_2 is the grid circuit capacity unit, T_1 and T_2 are the first and second low-frequency transformers, respectively, B is a valve holder which is used as a socket connector for the battery wires

in the hinged portion of the cabinet back (Fig. 11). The anode, or odd pin, is arranged at the bottom.

The transformers are next to be fitted. The cores must be placed at right angles, as shown, in order to eliminate interference between each other. If Igranic transformers are fitted, place them in the same relative positions as shown in the illustration, *i.e.* with the primaries and secondaries facing the proper ways.

The coil winding and final connecting is all that remains to be done. It is in the coil winding that care and patience must be shown in the construction, and the instructions given must be followed closely if good results are to be obtained.

Cut a ring $1\frac{1}{8}$ in. long from the piece of ebonite tube. This will serve as the former for the tapped aerial coil. There are 43 turns on this coil, and it is bank-wound. Before winding the bracket which supports this former may be fitted. The dimensions of this bracket are given in Fig. 7. It is secured to the former by two 6 B.A. screws, which are fitted into holes tapped in the side of the tube. Drill two little holes, Fig. 8, in the tube, close together and near the edge, to hold the start and finish of the coil in place. Shellac varnish is essential in winding this coil, and it must be fairly thick and tacky, for winding a layer-wound coil is next to impossible without a good adhesive varnish. The photographs will give a good indication as to the method of winding. (*See also* Bank Winding.)

Thread the end of the winding through the two holes on the bracket side of the former. It will be found that the friction will be sufficient to prevent slip, even if a good pull is given. Now wind on two complete turns as closely together as possible. The third turn is wound on the top of the other two in the hollow formed between them. Shellac must be applied to the tube on the portion to be wound before every turn. All wire wound straight on the tube must be pulled very tightly, otherwise, when the top wire is wound, it will be forced apart.

After the third turn has been wound, the fourth is laid alongside the second. Then the fifth between the third and fourth, and so on, until 43 turns have been wound. When these are complete, cut the wire off and thread the end through the anchoring holes. All that now remains is to arrange the tappings as shown in Figs. 3 and 4. This must not be attempted until the shellac is quite dry and hard. The tappings are taken as follows: the start, 3rd, 7th, 13th, 21st, 31st and the end. It will be noted that all the tappings are taken at the odd numbers, and these are, in every case, the top layer turns.

A simple way of making the tappings is to insert the blade of a pocket-knife under the place to be tapped. Then lever the wire upwards, stretching it slightly, so that it projects above the rest of the coil. Now scrape the cotton just off the raised portion. Not only will this bare the insulation, but it will remove any tarnish from the copper and render it in good condition for soldering. It will be advisable to tin the tappings straight away. A minimum of fluxite should be used for this job, because if it splutters when heated, and spreads, the insulation will be affected.

The two coils on the longer piece of coil may now be proceeded with. The first, or small coil, is the reaction-stabilizer winding, and consists of 34 turns of S.W.G. c.c. wire. The end of the wire may be secured in the same manner as for the bank-wound coil, namely, by threading the wire through two small holes placed side by side. Reference to Fig. 4, showing these two coils on the one tube, will make it appear that there are three coils. This is not so, however. The larger coil is divided about its centre, as shown diagrammatically in Fig. 9. The idea of doing this is merely to elongate the coil to a length of $3\frac{1}{2}$ in., which length is identical with the diameter of the tapped aerial coil. Start winding this coil about $\frac{1}{8}$ in. from the first coil, and in the same direction. Put on 32 turns close together, then for the thirty-third turn spread the wire for about $\frac{1}{4}$ in., after which the remaining 32 turns, making 65 in all, may be wound. These coils must be wound very tightly, as no shellac may be used.

All the coil winding is now complete, and the brackets (identical in height with that on the tapped coil former) may be fixed. The single turn inductance must now be

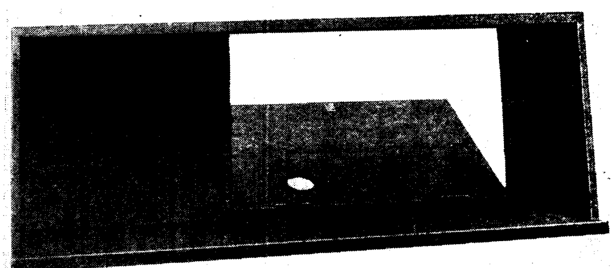


Fig. 11. At the back of the cabinet a hole will be seen in the hinged flap. This corresponds with the position of the valve-holder battery-connector

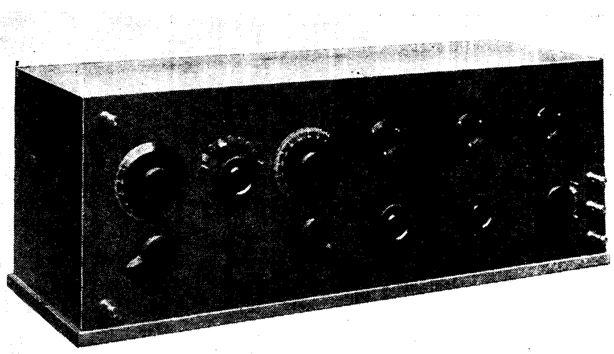


Fig. 12. When the cabinet is closed and complete the appearance is as here shown. Its construction is seen in Fig. 11 (above). Note the holes opposite the valves for watching the filaments. Aerial and earth terminals are, respectively, at top and bottom on the left, telephone terminals on the right

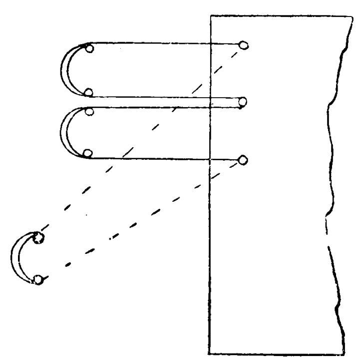


Fig. 13. In Fig. 12 it will be noticed that three telephone terminals are used. This diagram shows how they are attached when more than one pair of telephones are employed

HOUSING THE COCKADAY SET AND ATTACHING TELEPHONES made. This consists of the ⅛ in brass wire, bent in the form of one complete circle. It should be bent around a circular former of about 3 in. in diameter, and if this is done, it will be found to form a nice spring fit around the reaction-stabilizer coil. This single turn must be fitted in place about the centre of the reaction-stabilizer winding, care being taken primarily to see that the insulation on the latter is in perfect condition.

How the Coils are Mounted

The coils are now fitted on to the baseboard. The tapped coil must be fitted first, and then connected up the switch studs, using the tinned wire for the leads. The start of the coil is connected to the right-hand stud, looking towards the front of the panel. This having been done, complete all the connexions on the panel in the region of this coil as far as possible, for the larger tube will be found to get in the way of the soldering operations, if it be fixed prematurely. Now screw the large coil down to the baseboard, placing the reaction-stabilizer coil at the aerial-earth terminal end. The large coil is placed immediately behind the tapped coil, and may be in actual physical contact with it.

The wiring-up of the set must now be proceeded with. It is imperative that bare wire connexions be made, and that they should as far as possible follow the arrangement of those shown in the various photographs. Wiring in bare wire becomes quite easy with very little practice. First of all, reel off about 7 ft. or 8 ft. of wire and place one end in the vice, screwing up tightly. Take hold of the other end and pull very hard, putting sufficient tension on the wire to stretch it 3 in. or 4 in. This process will completely remove all kinks and bends.

After straightening cut it up into 2 ft. or 3 ft. lengths, taking care not to bend the wire in cutting. In soldering all connexions, use only the merest spot of fluxite, and take care to remove all traces with a rag dipped in petrol, after soldering. The whole job will be much facilitated if all brass parts are thoroughly tinned beforehand.

A good plan to ensure that all connexions are in order is to draw a pencil line alongside the printed lines on the wiring diagram, one by one, as each is soldered. By this means a mistake or omission is very nearly impossible. All the connexions may be traced out by a careful study of the photographs alone.

All that remains to be done now is to attach the wires to the battery connexion plug. A photograph of such a plug appears on page 411. The plug itself is the base from a burnt-out valve. All the inside is removed, leaving only the moulded base and the metal cap. A wire is threaded through the holes in the moulding and soldered on to each valve pin, in precisely the same manner that the original valve connexions themselves were fixed. The wires are just over 3 ft. in length, and have a piece of 1 mm. systoflex threaded over them, each of a different colour. The whole of the empty space inside the metal cap is filled in with Chatterton's compound.

The whole set is now complete, and may be screwed inside the cabinet, which appears as in Fig. 12. The battery plug should be inserted, and the following battery connexions made. A H.T. battery of 60 volts is best with tappings every 3 or 6 volts. The top wire on the plug goes to H.T. positive maximum ; bottom wire to H.T. positive tap for rectifier and should be plugged into 24 volts for a trial. Left-hand pin (looking towards front of panel) is L.T. negative, and right-hand, L.T. positive. In addition to this a wire must be connected from H.T. negative to L.T. positive. Aerial connexion is made to the top terminal on the left-hand side of the panel, earth to the bottom terminal on the same side, and the telephones as shown in the photograph and Fig. 13.

The soft rectifier valve is inserted into the left-hand socket, and the R valves into the remaining two. As a preliminary, turn up both filament rheostats fully. If all is correct, the set will be found to react strongly.

The Right Method of Tuning

The amplifier switch should be on the centre stud. Now rotate both main condensers very slowly indeed, until the carrier wave of a telephony station, or the whistle of C.W. is heard. Extreme slowness of rotation is essential, for the tuning is very sharp, and it is simple to pass right over a station without hearing it if the dials are rotated too quickly. Immediately a carrier is picked up, leave the condensers and rotate the seven-point switch until the tapping giving the loudest signal is found. If the telephony is now at all distorted, it will be found possible to eliminate this entirely by careful adjustment of the rectifier filament. The condenser on the left adjusts the reaction and that on the right the wave-length. Tuning on the first is nothing like so sharp as that on the one for the wave-lengths.

If the set has been constructed as described, all the broadcasting stations will be found to come in within about 30° of the wave-length condenser dial for the same switch setting. It is possible to pick up the same station with many different settings of condenser, switch and filament, and should a station be jammed on one setting, readjustment of controls to a new setting will be a certain cure. A little practice will soon show, however, the correct filament adjustment to bring in any telephony without reacting sufficiently to make their carriers audible. When the set is first used, distortion and difficulty of eliminating the carrier may be evident. This can be immediately cured by cutting down the filament current, the H.T. tap to the rectifier, or both.

Although signal strength is greatest when the switch arm in the L.F. current is on the centre stud, moving it to either the higher or the lower one will improve the tone of music.—*R. B. Hurton.*

COEFFICIENT. Number by which a quantity must be multiplied to give the value of another quantity. It may also be regarded as the ratio of one quantity to another.

In electricity and wireless coefficients of various ratios are constantly occurring. The following are the chief. The coefficient of amplification is the ratio of the effect produced with an amplifier to the effect produced without one. An important coefficient is the coefficient of coupling. This is defined as the ratio between the mutual inductance and the square root of the product of the individual inductances. If M be the mutual inductance, L_1 L_2 the inductances of the coils taken separately, the coefficient of coupling $= M/\sqrt{L_1L_2}$.

The coefficient of mutual induction is the inductive effect produced in one circuit when the current in the other is changing at the rate of one ampere per second. The coefficient of self-induction is the amount of induction in a circuit produced by a similar rate of change of current. *See* Coupling ; Inductance ; Induction ; Radiation ; Resistance.

COERCIVITY or Coercive Field. In magnetism the reversed magnetic field necessary to reduce the magnetic induction in a material to zero from any specified value. Put simply, it is the magnetic force necessary to remove all residual magnetism in a material. The term coercivity is occasionally used for the ability of a material to retain magnetism.

COHEN, LOUIS. American wireless expert. Born in 1876, and educated at the Armour Institute of Technology, the University of Chicago and Columbia University, he was on the scientific staff of the Bureau of Standards, 1905-9. In 1910 he was appointed chief of the research department of the National Electric Signalling Company, and afterwards he became professor of Electrical Engineering at the George Washington University. Cohen is one of the leading American authorities on electrical oscillations, and has written a considerable number of papers on wireless subjects. In 1917 he patented his arc system of radio-signalling.

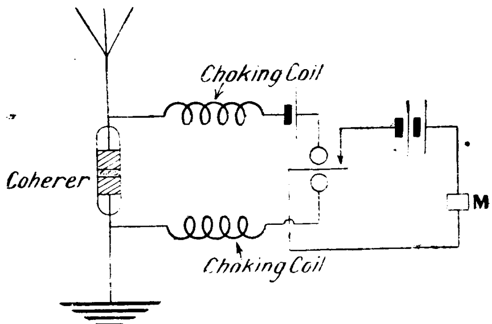
COHERER. An electric wave detecting device, so named by Lodge. Most coherers depend upon the fact that certain conductors when in a state of fine division are practically non-conductors for small electro-motive forces when loosely packed, but are good conductors for large electromotive forces. A mixture of particles of metal and poor conductors exhibit the same phenomena. C. and S. A. Varley, in their British patent taken out in 1866 for a lightning arrester, had two copper points, nearly touching, fixed in a small box filled with powdered carbon. In their patent specification they pointed out the fundamental principle of the coherer.

Hughes, in 1878, discovered that a tube of glass loosely filled with zinc and silver filings was sensitive to electric sparks at a distance.

But it was not until 1890 that the first real step was taken to make use of the phenomena of powdered conductors. In that year Branly published the account of his researches, in which he confirmed Hughes' observations and added that the electric spark had the power at a distance to change the conductivity of the powdered conductors. Branly carried out his experiments with a number of metals, and in 1889 Sir Oliver Lodge discovered a cohering effect when a very minute spark or scintilla passed between knobs, in connexion with his lightning guard experiments, as described in 1890 to the Institute of Electrical Engineers. In 1894 he exhibited his adjustable point device, the end of a fine spiral spring lightly touching an aluminium plate, which he called a coherer.

Marconi about the same period carried out a series of experiments, using different metal filings, and finally he brought out his first detector for wireless telegraphy. Marconi's coherer consisted of a sealed glass tube in which were placed two silver plugs attached to platinum wires. The inner ends of the plugs were cut at an angle, and brought within two millimetres of each other. The space between was filled with nickel and silver filings. Branly had found that after the filings in his coherer had been made conducting by an electric current, it required a slight mechanical shock to restore the filings to their original non-conducting state. Lodge provided this shock by means of an electric bell or a clockwork tapper, and an electro-magnetic tapper was employed by Marconi.

The application of the coherer to wireless telegraphy is as follows. The coherer is connected in series with a single cell,



CIRCUIT EMPLOYING A COHERER

In this diagram is shown how a coherer may be used in an aerial circuit with a relay to a recording instrument, M

or with a shunted cell, and galvanometer or other recording electrical device. In a second method the coherer is connected in series with a single cell and a telegraphic relay, operating with a current of less than a milliampere. In a third method a Bell telephone is in series with the coherer and a single cell and high resistance.

The resistance of the loosely packed filings is so great that the circuit of the cell to the relay, for example, is not completed, and the relay does not act. When ether waves act on the aerial of the receiving station, the oscillating electrical potentials set up in it act across the coherer, breaking down the resistance and completing the cell and relay circuit. In effect, the coherer is a closed tap which is opened by the action of the ether waves cohering or sticking together the metal filings. The filings remain in a cohered condition until they are decohered, and to detect the train of signals, therefore, the mechanical decoherer must be made part of the circuit.

The coherer has the disadvantages of being uncertain in its sensitiveness, and responding too readily to local and atmospheric disturbances.

Various forms of construction and various materials have been tried to overcome these defects, but they have not been very successful. The Castelli coherer (*q.v.*), with iron, mercury and carbon electrodes, has the advantage of being self-restoring. The Italian navy coherer, a modification of Castelli's, consists of a small glass tube with two iron or steel plugs between which is a small drop of mercury, and automatically decoheres.

Another form of self-decoherer is the Lodge-Muirhead. This consists of a steel disk slowly rotated by clockwork and just touching a globule of mercury which is covered with a thin film of paraffin. Normally the oil insulates the wheel from the mercury, but when oscillating potentials are set up in the receiving circuit, the insulation is broken down and the coherer circuit is completed. The steady rotation of the steel disk continually restores the coherer to a sensitive condition.

Walter's adjustable tantalum coherer also makes use of mercury. A tantalum wire, sealed in glass, just dips below the surface of the mercury, and the arrangement of the coherer is such that it will withstand shocks or tapping without affecting the sound.

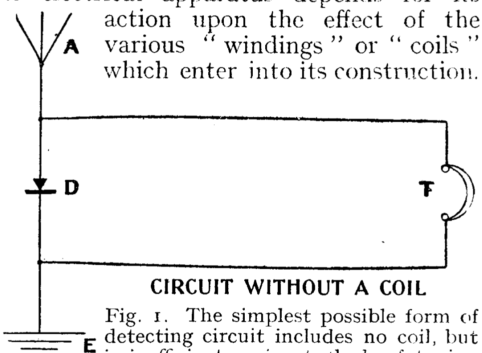
The theory of the coherer is not fully understood. Lodge suggested that the surfaces of the metal were welded together, a suggestion that has been supported by a number of others. Sundorph, Tommasina and others assert that a chain of conducting particles are formed. But with both Lodge's theory and that of Sundorph, large differences of potential are necessary to observe the phenomena; much greater than those due to ether waves. It is clear that the action is an electrical one and depends upon light contact, and probably there is a passage of negative ions from one surface to another. *See* under the names of various coherers—Blondel; Branly; Castelli; Lodge-Muirhead; Marconi; also Valve.

COILS: (1) TYPES, USES AND THEORY

Inductance Coils for All Purposes with Theoretical Calculations

Here the general principles underlying the design and use of inductance coils are explained with standard examples and discussion of the calculation of inductance and capacity values. Then follow two further sections covering the best methods of making and winding coils. See also under the names of specific coils, e.g. Bank-wound Coils; Basket Coil; Honeycomb Coil, etc.

This term is used in a very elastic sense in electrical phraseology. Its usual significance is to convey the idea of a number of turns of insulated copper wire carrying an electric current for the purpose of producing various electric and magnetic phenomena. To the motorist it is a term conventionally reserved to the apparatus used for ignition; the radiologist or physician would understand it as an appliance for supplying high-tension current to focus tubes and high-frequency apparatus in general. In fact, it is a term capable of very wide interpretation, since, whether used in a "wireless" sense or otherwise, almost any form of electrical apparatus depends for its action upon the effect of the various "windings" or "coils" which enter into its construction.



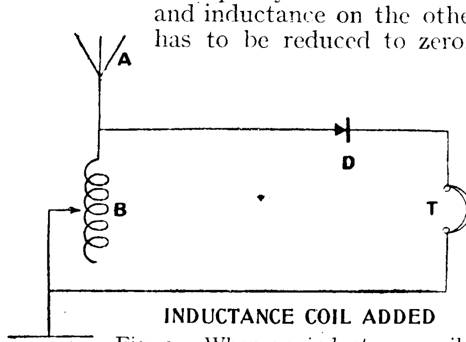
CIRCUIT WITHOUT A COIL

Fig. 1. The simplest possible form of detecting circuit includes no coil, but is inefficient owing to lack of tuning

Coils are used in the construction of armature and field magnets of dynamos, electric motors, and alternators, of solenoids or electro-magnets, for various forms of measuring instruments such as galvanometers, ammeters, volt-meters, wattmeters, ohmmeters, ampere-hour meters, transformers, resistances, inductances, choke coils, etc., but so far as wireless work is concerned inductance coils and transformers are the principal items encountered, omitting resistance for control of current, which also takes the form of a coil in the majority of instances.

To take the case of the simplest possible form of detecting circuit, Fig. 1 illustrates what may be done without coils of any description, save those entering into the construction of the telephones. A is the aerial, D a crystal detector, and E the earth. The telephone circuit, T, is a simple shunt across the two sides of the detector. Such a circuit responds to rather a wide range of wave-lengths.

Fig. 2 obviates this disadvantage by introducing an inductance coil at B, enabling the circuit to be tuned to the wave-length of the incoming signal. This was introduced in Lodge's patent of May, 1897, which has been established in the Courts as the fundamental tuning patent. It was extended for seven years, and then purchased by the Marconi Company. A coil of this type is illustrated in Fig. 6, and by adjusting the sliding contact to include more turns of the inductance coil the receiving aerial responds to longer wave-lengths; by reducing the number of included turns it responds to shorter wave-lengths. If the incoming wave-length is shorter than the natural wave-length of the aerial itself, the aerial has to be tuned to resonance by inserting a condenser in series with the earth. To tune an oscillating circuit for reception of waves at a given frequency its reactance, due to the joint effects of capacity on the one hand and inductance on the other, has to be reduced to zero.



INDUCTANCE COIL ADDED

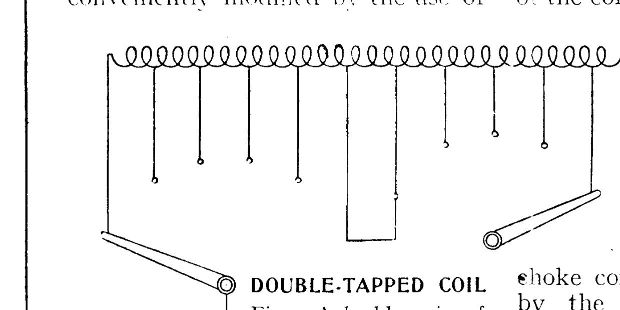
Fig. 2. When an inductance coil is added to a simple circuit it is employed in the position shown at B, and enables the circuit to be tuned to the incoming wave-length

Inductance coils may take the form of a single layer of wire wound on a circular support called a former, with or without a sliding contact which is adjustable for any position from end to end, and cuts in or cuts out one turn of wire at a time as it is moved; or they may have tappings taken out at regular intervals, as illustrated in

Fig. 5, and connected to a series of terminal studs, which a switch lever traverses in steps, or with two separate sets of tappings, as shown diagrammatically in Fig. 3. Multiple-layer inductance coils are not generally employed, as their self-capacity between adjacent layers of wire has been found objectionable at high frequencies.

Instead of a single-slider inductance, the use of a double slider on the coil enables a finer adjustment and more exact tuning to be made. Such an arrangement appears diagrammatically in Fig. 4.

The amount of aerial energy transferred to the receiving circuit is conveniently modified by the use of "coupled" coils acting inductively, one upon the other, without any actual electrical connexion existing between them. In coupled circuits the energy is conveyed entirely by means of the mutual magnetic field, and according to the degree of mutual induction the two circuits are said to be tightly or loosely coupled together. Variable inductance coils consist of one coil on a fixed support containing an internal and separate coil on a movable sliding tube, which can be withdrawn more or less out of the influence of its neighbour, as in Fig. 7. The variometer type of inductance coil, Fig. 9, consists of two coils joined in series with one another and either plain or tapped, and so shaped that one can be rotated within the other until their planes lie anywhere between 0° and 180° apart. When their respective planes are coincident at 0° they act cumulatively; when at 180° differentially; while the intermediate positions afford a very convenient means of obtaining a delicate adjustment



DOUBLE-TAPPED COIL

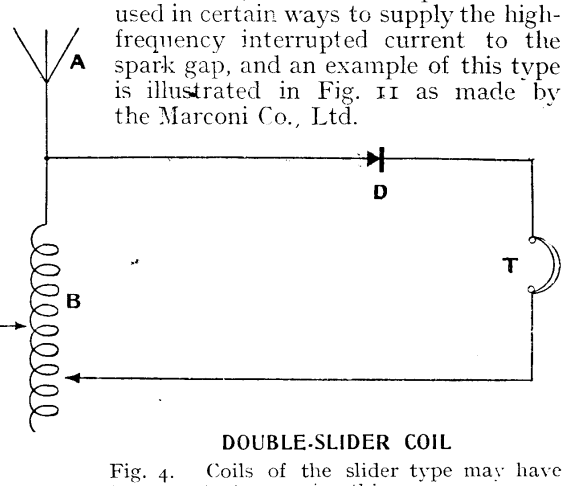
Fig. 3. A double series of tappings taken out at regular intervals, as represented diagrammatically, may be taken off one coil when two switches are used

Inductance coils or transformers designed for high-frequency (radio-frequency) have air coils, that is to say, their inductance effects are sufficiently great without the assistance of an iron core owing to the excessively high frequency of the circuits upon which they are used. Low-frequency or audio-frequency transformers and inductances, on the other hand, require an iron core to attain the desired inductance effect without employing an excessive number of turns of wire in their coils.

Impedance or choke coils, Fig. 8, have a nearly closed magnetic circuit, but an air gap is provided so that the inductance of the coil will remain practically constant for a wide range of frequencies. If the magnetic circuit were entirely closed the inductance would vary with the frequency, but as the reluctance of the air gap is unity for all frequencies, the air gap becomes the controlling factor in a choke coil.

Another type of air core choke coil is shown in Fig. 10 as made by the Marconi Co., the function of which is in one application to prevent the current from a high-frequency condenser discharge surging back into the low-frequency circuit. This is accomplished without interfering in any way with the low-frequency current. Each coil is wound with fine wire in one single layer on an insulated support. The whole is placed in a teak case, and this is mounted on porcelain insulators.

In transmission work a spark coil is used in certain ways to supply the high-frequency interrupted current to the spark gap, and an example of this type is illustrated in Fig. 11 as made by the Marconi Co., Ltd.



DOUBLE-SLIDER COIL

Fig. 4. Coils of the slider type may have two contacts, as in this case, or more, according to the circuit requirements

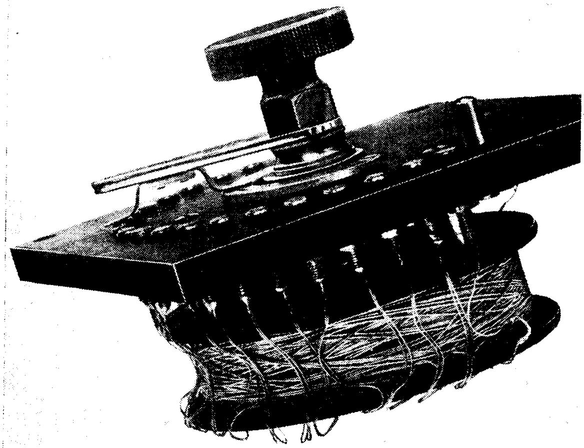


Fig. 5. Tapped coils may be self-contained, as in this case. Here a stud switch forms an effective base, to which the coil is attached

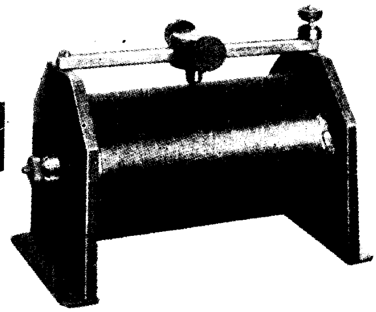


Fig. 6. Single-slider coils are used for simple circuits. They consist of two wooden cheeks with slider bar across the top, spring contact, coil, and terminals

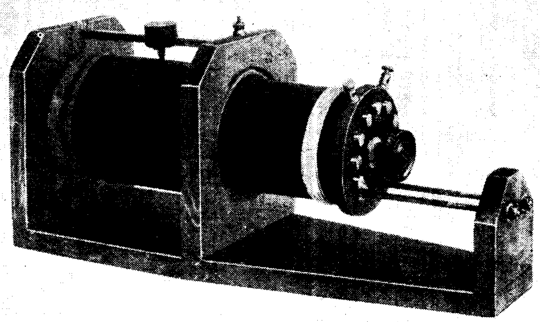


Fig. 7. Loose-coupled coils for coupled inductance may have a reactance coil added. Above will be seen a loose coupler, with a third coil (white) for reactance purposes

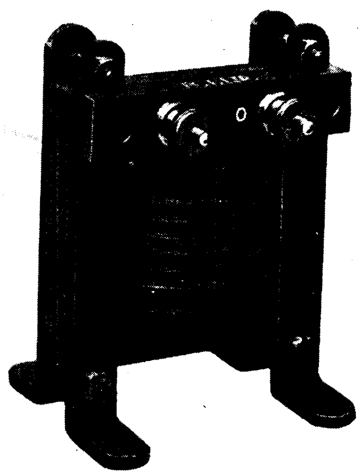


Fig. 8. Iron core choke coil. This is an impedance coil having a nearly closed magnetic circuit

Courtesy Radio Instruments, Ltd.

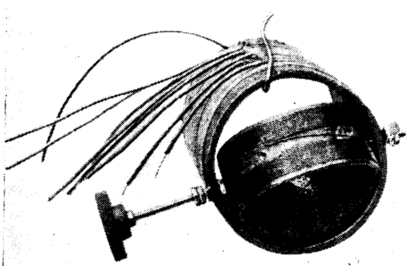


Fig. 9. Inductive effect can be changed between two coils by arranging them in this way. The smaller coil turns on a pivot inside the larger coil. Together they are known as a variometer

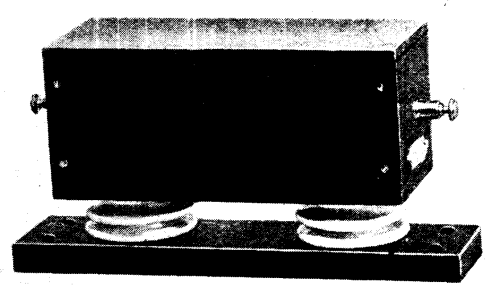


Fig. 10. Air core choke. This coil is used to prevent the current from a high-frequency condenser discharge surging back into the low-frequency circuit

Courtesy Marconi Wireless Telegraph Company.

SOME INDUCTANCE AND OTHER COILS USED IN WIRELESS APPARATUS

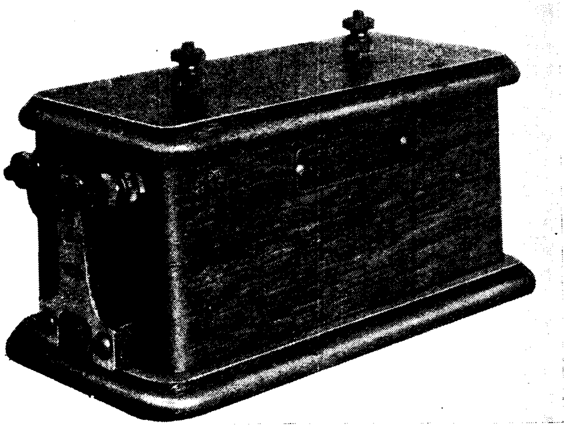


Fig. 11. Spark coils, an enclosed example of which is here shown, are used for transmission work to supply the high-frequency interrupted current to the spark gap

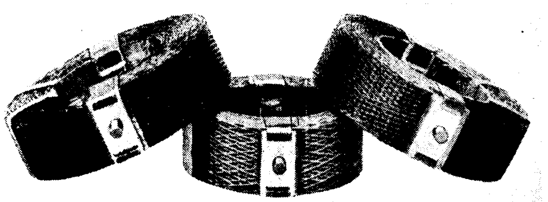


Fig. 12. Three Igranic (De Forest) gimbal-mounted coils are shown. These are a variation of the coil in Fig. 13. They are wound by a special system, whereby the self-capacity is reduced

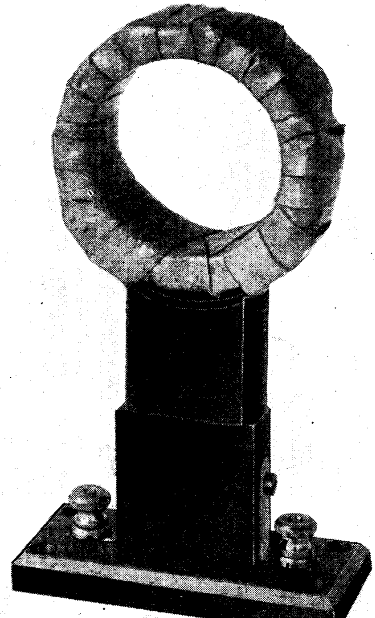


Fig. 13. Burndept plug-in coils of this type consist of a layer or layers of wire wound on a circular former connected to a plug-in holder

COILS USED FOR TRANSMISSION AND RECEPTION

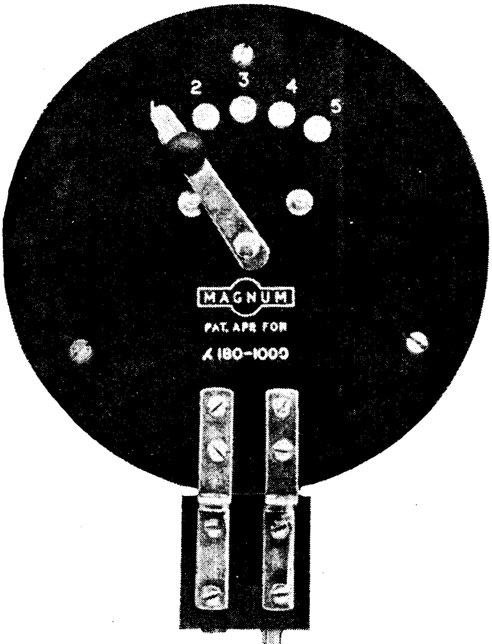
The experimenter is mostly concerned with coils for inductance purposes, and a convenient form is illustrated in Fig. 13, and is known as a Burndept coil (*q.v.*). This is typical of a number of makes, and consists essentially of a layer or layers of wire wound on the outside of a former or tube, which is attached to an ebonite holder with two contact plugs. These push into corresponding contacts in the base or holder.

Variations of the same idea are shown in Fig. 12, and are known as Igranic or De Forest coils. These are wound by a special system, explained under the headings De Forest Coils and Duo-lateral Coils (*q.v.*), whereby the self-capacity is reduced and the efficiency increased. The method of mounting is known as gimbal, because the coils have pivot-like bearings on them which fit into a suitable holder and permit the coil being adjusted to the best advantage, as explained under the heading Coupling (*q.v.*).

A coil that combines the advantages of a tapped coil with those of a plug-in type is illustrated in Fig. 14, and is known as Magnum, produced by Burne Jones Co. The tappings enable a fairly wide range of wave-lengths to be covered on the one instrument. The windings are on the space-layer principle, a number of coils being wound on circular formers of varying sizes, arranged concentrically and connected in series. Tappings are taken off at equal intervals, and so arranged that an ordinary 0·0005 mfd. variable condenser bridges the gap and covers the wave-lengths between the stud tappings, while allowing sufficient overlap for efficient tuning. The windings are totally enclosed by the ebonite casing. This type of coil can be used with the advantage that the one instrument covers a wide range of wave-lengths.

From the point of view of the beginner the use of the characteristic coils are briefly as follows.

Inductance coils are used to tune a circuit or bring it into harmony with the wave-length of the transmitting station to which it is desired to listen. To do this it is virtually necessary to lengthen or increase the inductance of the coil to listen to long wave-lengths. The comparatively short wave-lengths of the broadcasting stations only call for a small coil, but as the variations in wave-length of the different broadcasting stations are small, the adjustment of the length or inductive value of the coil has to be very well done, or interference will result from a station at a nearly similar wave-length. This adjustment is provided for by a sliding contact on the coil or by tappings, or a number of ready-wound coils such as the Burndept or honeycomb type can be placed in a holder and changed as desired. Another way of doing the same thing is to use a variometer, where the apparent length of the coil is changed by turning one end in under the other, and thus making the inductance of the one part increase or diminish that of the other.



MAGNUM COIL

Fig. 14. Combined in this tapped coil are the advantages of its type and those of a plug-in coil. The windings are on the space-layer principle

Inductance of Single-layer Coils. The inductance of a wire will vary considerably, depending on the shape into which the wire is bent.

As each different shape of coil necessitates the use of a different formula if its inductance is to be calculated, it is better to refer to the formulae published by E. B. Rosa and L. Cohen in the Bureau of Standards for those coils which are not in general use.

For coils with air cores wound in a single layer, with the turns close to one another, the inductance may be found from a formula given by Professor Nagaoka:—

$$L = \pi^2 d^2 n^2 K,$$

where L = the inductance in centimetres,
d = the diameter of the coil in centimetres,
n = the number of turns per centimetre length of coil.

The above formula is for ordinary cylindrical coils with the turns close wound, having small air spacing between the turns, or thin insulation.

K is a constant depending on the ratio of the length of the coil and its diameter, $\frac{d}{L}$ varies between 0·01 and 10, and is given by Professor Nagaoka.

The following table giving the values of K to two figures will be found accurate enough for most practical purposes:

$\frac{d}{L}$	K	$\frac{d}{L}$	K
·00	1·00	·76	·74
·02	·99	·78	·74
·04	·98	·8	·73
·06	·97	·82	·73
·08	·96	·84	·72
·1	·96	·86	·72
·12	·95	·9	·71
·14	·94	·92	·70
·16	·93	·94	·70
·18	·93	·96	·69
·2	·92	·98	·69
·22	·91	1·00	·68
·24	·90	—	—
·26	·89	1·5	·59
·28	·89	2·0	·52
·3	·88	2·5	·47
·32	·87	3·0	·43
·34	·86	—	—
·36	·86	3·5	·39
·38	·85	4·0	·36
·4	·85	4·5	·34
·42	·84	5·0	·31
·44	·83	5·5	·30
·46	·83	6·0	·28
·48	·82	6·5	·27
·5	·81	7·0	·26
·52	·81	7·5	·25
·54	·80	8·0	·24
·56	·80	8·5	·23
·58	·79	9·0	·22
·6	·79	9·5	·21
·62	·78	10·0	·20
·64	·77	—	—
·66	·77	—	—
·68	·77	—	—

If it is desired to convert the inductance which is thus obtained in the absolute unit of the electro-magnetic system, *i.e.* in centimetres, into the practical units, *i.e.* the henry, the millihenry, and the microhenry, these relationships are as follows :—

1 henry $= 10^9$ centimetres,
1 millihenry $= 10^6$ centimetres,
1 microhenry $= 10^3$ centimetres.

Multiple-layer Coils. For closely wound coils, of a single or multiple layer, and of almost any proportion, there is a very good empirical formula given by Brookes and Turner.

Again working in centimetres, this is

$$L = \frac{4\pi^2 a^2 N^2}{b + c + R} F_1 F_2$$

where a = mean radius of the winding,
b = the length of the coil,
c = the thickness of the winding,
R = the outer radius of the winding,
N = the total number of turns,

$$F_1 = \frac{10b + 12c + 2R}{10b + 10c + 1{\cdot}4R}$$

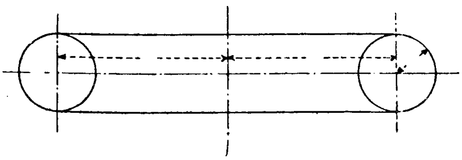
$$F_2 = {\cdot}5 \log_{10}\left\{100 + \frac{14R}{2b + 3c}\right\}$$

If the coil is a multi-layer one, having a length several times as great as its diameter, this formula may be reduced to

$$L = \frac{4\pi^2 a^2 N^2}{b + c + R}$$

which in general will give results near enough for practical purposes.

Toroidal Coil. For a circular coil, the winding of which also has a circular cross



COIL THEORY

Fig. 15. Inductance and capacity are considered in this diagram of a circular coil having a circular cross section

section (see Fig. 15), Alex. Russell gives in "A Treatise on Alternating Current Theory," Vol. 1, p. 52,

$$L = 4\pi n^2 (R - \sqrt{R^2 - a^2})$$

where R = mean radius of the coil,
a = radius of its cross section,
n = number of turns.

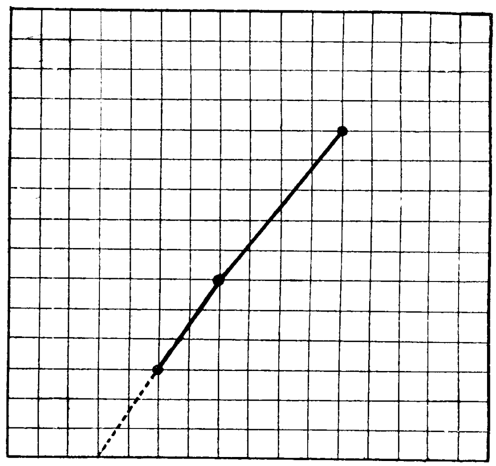
Inductance of Flat Coils. For flat coils at low frequencies, a good formula is given by Rayleigh and Niven :

$$L = 4\pi a n^2 \left\{\log_\epsilon \frac{8a}{c} - \frac{1}{2} + \frac{c^2}{96a^2}\left(\log_\epsilon \frac{8a}{c} + \frac{43}{12}\right)\right\}$$

where c = the radial width,
n = the total number of turns,
a = mean radius of coil.

Capacity of Coil. The self-capacity of a coil is generally measured rather than calculated, the necessary formulae for calculation becoming so cumbersome or difficult that the practical method of measuring is more satisfactory in every way.

A good method of measuring the self-capacity of a coil is due to Professor G. W. O. Howe. Full details appear in Professor Howe's paper of 1912 in Vol. 24 of the proceedings of the Physical Society under the title, "The Calibration of Wavemeters for Radio Telegraphy." This



CAPACITY OF A COIL

Fig. 16. Measurements of self-capacity in a coil are expressed in the form of a characteristic curve, as the above example

method consists in setting up the coil near to a circuit which is oscillating, and adjusting the frequency of that circuit till it is in resonance with the natural wave-length of the coil. Capacities of known value are then added across the coil, the wave-length of the coil and its condenser being noted in each case. The wave-lengths are squared and plotted against the values of the added capacities. The points of the curve thus plotted should be found to form a straight line. If this line is produced backwards till it cuts the axis along which the capacities are plotted, the distance along this axis to the point of interception (Fig. 16) will give the self-capacity of the coil.—*R. H. White.*

COILS: (2) HOW TO MAKE

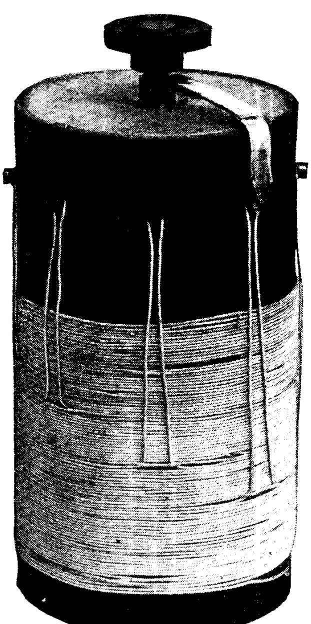
Simple Types of Inductances for Amateur Construction

Apart from standard coils of the plug-in and other varieties the experimenter frequently needs coils for specific purposes. Several ingenious methods of making coils are given here. Methods of winding will be found in the section that follows, and the methods of constructing specific coils under the specific headings, such as Basket Coil; Honeycomb, etc.

The wireless experimenter is always in need of coils of one kind or another, and the mode of their construction will, of course, be governed by the specific requirements of each individual case.

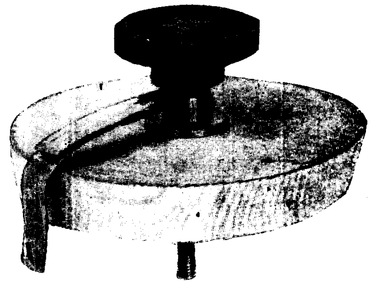
A particularly handy and simple type is illustrated in Fig. 1, and is suitable for general use as an inductance. It has the merit that it is easily and quickly made, is self-contained, and does not require a baseboard. In the form illustrated it is appropriate for experimental purposes, but if required for panel mounting, all that need be done is to extend the contact arm spindle and allow it to project through the top of the panel. The addition of a calibrated dial on the panel, and a pointer on the spindle immediately beneath the knob, completes the transformation.

The coil is wound on a cardboard tube 3½ in. in diameter and 12 in. long. The wire used is No. 24 gauge D.C.C., and the wave-length range is of the order of 200 to over 1,000 metres with the average P.M.G. aerial. If preferred the tube can be of ebonite, but cardboard, prepared as described under the heading Cardboard Tube, will answer most requirements. The top is closed with a disk of wood ¾ in. thick, cut to shape with a keyhole or pad saw, and trimmed up with a chisel and rasp.



SIMPLE TAPPED COIL

Fig. 1. By putting the switch knob on the end of the former and the studs on the face of the tube, the coil is made self-contained, and the switch does not require a baseboard



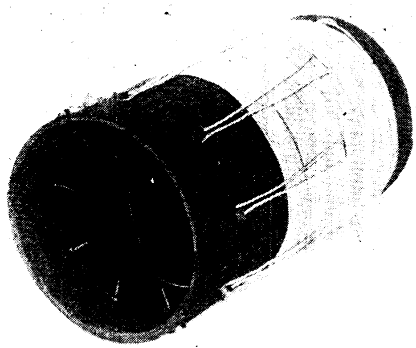
CONTACT ARM OF TAPPED COIL

Fig. 2. Plugged into the end of the former is a disk of wood, and the contact arm, as illustrated, is carried from the turning knob over the edge of the former to meet the studs seen in Fig. 1

It should be a good fit in the end of the tube, and has a central hole through it to take the contact arm spindle. This is fitted with the usual spring washer and brass bushing, the latter screwed to the top of the wooden end with small countersunk wood screws. The contact arm is made of two strips of phosphor-bronze or copper, attached to a slot cut across the boss of the knob and locked to the spindle with the customary lock nut.

These details are clearly shown in Fig. 2, from which it will be apparent that the end of the contact arm is bent to a right angle and afterwards rounded with a pair of round-nosed pliers to facilitate the passage of the arm over the contact studs. The example illustrated has nine equal taps, but any other number can be fitted by the same simple plan of drilling the requisite number of holes through the tube about 1¼ in. from the top, passing an ordinary contact stud through each hole, and securing with a nut on the inner side of the tube, as shown in Fig. 3. This also illustrates the winding and the method of taking the tappings.

The winding commences near to the top, and several turns are made. The wire is then turned up at right angles around a contact stud, and back to the starting point, as shown in Fig 4. The



TAPPINGS OF SELF-CONTAINED COIL

Fig. 3. Contact studs are fitted to the tube, and the mode of taking off the tappings is apparent in this photograph. The contact studs are held in position by nuts

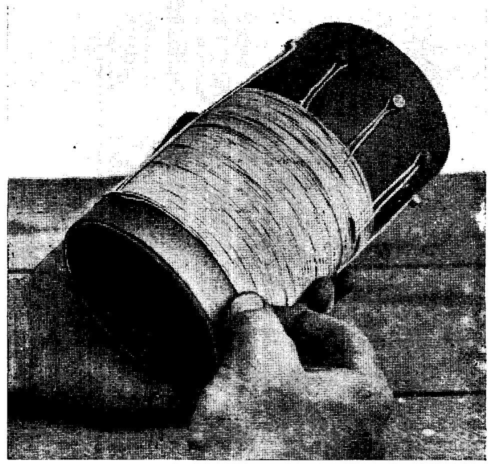
next turn of the wire then passes over the little loop-like portion of the winding, and thus holds it fast, as shown in Fig. 5. The winding and tapping are continued until the last of the turns has been taken and the end of the wire is fastened to the tube by passing it through holes drilled in the usual way, as described in the article on coil winding. One of the studs is then removed and the insulation cleaned off the wire, and the stud replaced in the bight of the wire. It is then given a twist which tightens the wire and makes good contact to the stud, which is afterwards replaced in the tube and the lock nut tightened.

Each of the studs is dealt with in the same way, the two ends of the windings made fast, and the starting end brought out of the tube and connected to the aerial or other terminal. The top of the coil is the next part to fix, and is simply secured with glue and a few fine screws or brads. These should be of brass, not iron or steel. One wire is attached to the contact arm spindle, and taken to the instrument in any desired manner according to the purpose.

Another type of inductance coil, with considerable possibilities, is illustrated in Fig. 6, and is of somewhat unusual design. It consists of a baseboard with a ring of equally spaced valve legs, around the outside of which is wound the No. 24 gauge enamelled copper wire. Tappings are taken to each valve leg, and in all twenty turns of wire are wound around the legs. A tap is taken at each two turns, and, roughly, four valve-leg spacings represent 400 metres wave-length with the average P.M.G. aerial as used by the amateur for reception purposes. In one

METHOD OF WIRING STUDS

Fig. 4. Tappings are being made by bending the wire at right angles and taking it up to the studs and back a ain and the winding continued



FINISHING OFF TAPPINGS

Fig. 5. After the tapping has been completed the next turn of wire holds the loop firmly in place

Printed and Published every alternate Tuesday by the Proprietors, The Amalgamated Press (1922), Ltd., The Fleetway House, Farringdon Street, London, E.C.4. Sole Agents for South Africa: Central News Agency, Ltd.; for Australasia: Messrs Gordon & Gotch, Ltd.; and for Canada: The Imperial News Co., Ltd. (Canada). Subscription Rates: Inland and Abroad, 1s. 5d. per copy. January 1st, 1924.
D/R