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INDEX

VOLUME X (New Series) 1950

SUBJECTS

* Pages 195-212 appear by error in both the May and June issues. An asterisk denotes that the reference will be found in the June issue.

PERSONS

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Group Captain Sydney Lugg was born in Bournemouth where he received his early education. Entering the Royal Air Force as an Aircraft Apprentice, Group Captain Lugg took one of the first three-year full-time courses at the Wireless School, Flowerdown, and subsequently he specialized as a Signals Officer, having previously qualified also as a pilot and a flying instructor.

Before the war, his overseas tours included service in China as a Signals Officer. Subsequently, he has been engaged at experimental stations and on radio location and in 1944 he was awarded the C.B.E. in recognition of his work as Senior Radar Officer in the North African Campaign.

Group Captain Lugg was elected a Member of the Institution in July 1942 and a member of the General Council in September 1949.

He is at present in the Directorate of Radio, Air Ministry, and is responsible for the engineering aspects of all radar and radio equipment fitted in aircraft.

Horace Albert Brooks was born in Oxford on December 6th, 1893, and served in the Telegraphist Branch of the Royal Navy from 1909 to 1933. During the latter part of his service, Mr. Brooks was an instructor to officers specializing in wireless and signals and principal assistant editor of the first Wireless Instructional Handbooks for the Royal Navy.

On retiring from the Royal Navy, he took up a civil service appointment under the Director of Scientific Research and was responsible for the production of all Handbooks for W/T instruction in the Royal Navy.

He is now employed in the Royal Navy Scientific Service under the Director of Research Programmes and Planning.

Mr. Brooks was elected an Associate Member of the Institution in June 1935 and after serving on the Membership Committee he was elected a member of the General Council from 1939 to 1940. He was again elected a member of Council in September 1948 and has this year also been elected a member of the Professional Purposes Committee.

William John Thomas was born in Llanelly, South Wales, on July 23rd, 1912. He received his technical education at the University College of Wales, Aberystwyth, obtaining a first class honours degree in Physics in 1933. After completing his year of professional training in the Teachers' Training Department, he pursued research work at the College until 1937, and was awarded the Ph.D. degree for his thesis on "An eddy current method of determining specific heats."

After a short period as an Education Officer at the Electrical and Wireless School, R.A.F., Cranwell, he was seconded to the Ministry of Supply in 1940, and in 1942 was appointed Senior Instructor at the Army Radio School, Petersham, Surrey.

At the end of the war he returned as Senior Physics master at the Queen Elizabeth Grammar School, Carmarthen, and in 1947 was appointed Head of the Science and Technical Department and Deputy Principal at the Norwood Technical College, S.E.27.

Dr. Thomas was elected an Associate Member of the Institution in June, 1947, and has served on the Education and Examinations Committee since June, 1948. He was appointed a member of the Council in November, 1948.

MATERIAL SPECIFICATION and PREFERRED VALVES

Specification of Radio Materials

The high standards required of radio apparatus today make it necessary for the correct materials to be used in the manufacture of such apparatus and its constituent components. The Radio Industry Council has, therefore, recently published Specification No. RIC/1000/A. This specification is described as a guide to manufacturers in the choice of materials for radio and electronic equipment and for components used in that equipment, no attempt has been made to include materials which have only a limited or highly specialized application. It is intended to provide the industry with help in settling its own materials problems along lines comparable with those on which the Inter-Service Specification RCS/1000 helps the Services to deal with their distinct but similar problems. It is hoped that eventually the relevant sections of both these specifications may be linked together in one national standard to be published by B.S.I.

The specification has been divided into the following Sections :—

Section 1. Preface.

Section 2. Metallic Materials.
- 2.1. Ferrous Metals.
- 2.2. Aluminium and Aluminium Alloys.
- 2.3. Copper and Copper Alloys.
- 2.4. Solders.
- 2.5. Zinc and Zinc Alloys.

Section 3. Plastics.
- 3.1. Thermo-setting.
- 3.2. Thermo-plastic.

Section 4. Elastomers.

Section 5. Inorganic Insulating Materials.

Section 6. Insulating, Filling and Sealing Compounds.

Section 7. Textile Materials and Papers.

Section 8. Timber.

Section 9. Lubricants.

Section 10. Wire and Sleeving.

Section 11. Miscellaneous Materials.
- 11.1. Adhesives.
- 11.2. Fluxes.

It has been prepared jointly by the Technical Specification Committee of the R.I.C. and the Materials and Finishes Sub-Committee of the R.I.C. in consultation with the British Radio Equipment Manufacturers' Association, the Radio Communication and Electric Engineering Association and the Radio and Electronic Component Manufacturers' Federation. It has been approved for publication by the Technical Directive Board of the R.I.C., on which all the constituent associations of the R.I.C. are represented, but has not yet reached the stage of consideration by the British Standards Institution.

Copies of the specification are obtainable from the Radio Industry Council, 59 Russell Square, London, W.C.1 for 3s. 6d. each, post free.

A further guide dealing with "Finishes" is being prepared by the R.I.C. but it is not expected to be completed until well into 1950.

The R.I.C. in conjunction with the Radio Communication and Electronic Engineering Association have also recently published Specification No. RIC/271/A—Pin Connectors of Piezo-Electric Quartz Crystals mounted in B7G Valve-type Envelopes. A limited number of copies are available from the Radio Industry Council, 59 Russell Square, London, W.C.1, price 1s.

S.I.M.A. List of Preferred Valves

In order to simplify problems in the use of thermionic valves in scientific instruments from the point of view of design, servicing and export conditions, the Electronics Section of the Scientific Instrument Manufacturers' Association has prepared a list of preferred types of valves. A preliminary list was issued to members of the Section in 1947 and this printed edition now brings the original up-to-date. Miniature valves are included in a new section and also a number of miscellaneous types, apart from those used for amplifying and rectifying.

Periodical review will take place for the possible inclusion of new valves as they appear on the market.

AN AERIAL COMPARATOR AND MONITOR UNIT*

by

J. D. Storer (*Graduate*) and S. Southgate

SUMMARY

The paper describes a system for improved aerial selection and signal monitoring at receiving centres. The system enables any available aerial to be applied, via a coaxial switch, to a monitoring receiver whose output at intermediate frequency is displayed on the screen of a cathode ray tube ; thus providing monitoring facilities at any frequency on any aerial.

It also provides facilities for any two aerials to be switched alternately on to the monitoring receiver, either manually or at high speed by electronic means, in order that a visual comparison may be obtained between the two aerials on a cathode ray tube whose time base is locked to the aerial switching speed.

1.0. Introduction

The arrangement most commonly used at receiving centres for the reception of long distance high speed and multi-channel telegraph transmissions, is the use of some form of diversity system, and a schedule of frequency changing related to the maximum useable frequency pertaining at particular times.

In the majority of cases, double or triple diversity is employed and the signals derived from each aerial are fed into a path selector or gate circuit which may be adjusted to pass the more powerful signal at any instant. It should be noted that such a system selects the most powerful signal, and it is possible that if an interfering signal of different modulation frequency is present on the same carrier frequency, the aerial with the maximum power present may not necessarily be the one which will give the greatest signal readability.

As an approximation it may be said that an improvement in signal of from 6 to 8 db is obtained by using a double diversity system, and a further 4 db by a triple diversity system. This form of diversity is entirely satisfactory with properly designed aerials, such as are normally available on commerical point-to-point links. At some signal centres, however, lack of space coupled with a large number of transmissions to be received, make it impossible for correctly designed diversity aerials to be available for every required signal. In such cases the aerial system will be designed on a compromise basis to obtain reasonable results on all required transmissions.

* Manuscript received October 25th, 1949.
U.D.C. No. 621.396.662.

It is obviously not possible to combine all the available aerial arrays in a diversity system, although it would seem that such a system would produce the highest percentage of readability. However, with the comparator, it is possible to examine the performance of all the available aerials on any particular transmission, and to select a pair which have good signal/noise ratios and produce the most suitable signals for diversity working.

It should be noted that this system does not attempt to provide diversity working by switching between two aerials at a constant speed ; such a system would suffer from the obvious disadvantage that in the case of one aerial delivering a good signal, and the other zero or low signal due to a fade, the good signal would be applied for only 50 per cent. of the time and the average level of signal fed to the receiver would be halved.

The comparator enables the selection of a pair of aerials which are most suitable for diversity reception of a particular transmission. The selected aerials are then fed direct to the receiver and a normal diversity path selector or gate circuit is employed. It is also possible to compare the signals obtained from two similar aerials ; thus the relative efficiency and signal/noise ratio at any instant may be measured directly.

A further advantage provided by such a system is that the signal being fed to any working receiver may be tuned in on the monitor receiver and viewed on the display unit, thus providing the facility of monitoring from a single control point, the signals being applied to any working receiver at any instant, without interfering with its adjustment.

Fig. 1 shows a block diagram of the system ; it will be noted that with the coaxial switch "A" in position one, and the comparator unit locked over to switch "A", the monitor receiver will be supplied with the same aerial as number one working receiver, and if tuned to the same frequency, the signals displayed on the cathode ray tube will be directly related to those applied to the working receiver. It is assumed that the receivers are aligned to have an almost identical performance.

2.0. The Comparator

2.1. *Basic Considerations*

Fig. 2 shows a block schematic of the comparator. Facilities are provided for comparing two signals at radio frequency to enable the selection of a pair of aerials suitable for double diversity working. In view of the facts that, (*a*) double diversity is more general than triple diversity and (*b*) if the link is of sufficient importance to justify the added expense of triple diversity, aerials of optimum design will almost certainly be available ; it was considered that the complex circuitry needed to increase the number of aerials which could be compared was not warranted.

When the aerial input to the receiver is being switched electronically at high speeds it is impossible to tune the receiver aurally, as a modulation of magnitude proportional to the difference in the signal levels between circuits A and B, and having a frequency equal to that of the multivibrator, will be audible—Fig. 3.

It is still possible to tune the receiver visually on the display unit but, as this is not always entirely satisfactory, a locking voltage is provided via a manually operated switch, to hold either circuit conducting. This enables the receiver to be tuned with a fixed aerial applied, and also allows the aerials to be compared at the manual switching speed.

The intermediate frequency output of the monitoring receiver is fed via an amplifier stage to the cathode ray tube, the time base of which is synchronized from a voltage pulse obtained by differentiating a square wave output from the multivibrator. Precautions are taken to prevent the time base oscillator from pulling the frequency of the multivibrator.

It is essential that no limiting shall take place in the amplifier circuits of the comparator, or the monitoring receiver, otherwise a true comparison of the signals will not be observed.

2.2. *Detailed Circuitry*

A complete circuit diagram of the comparator is shown in Fig. 4. The signals from the two aerials selected by the coaxial switches are each fed via an equalizing circuit to the control grid of a triode hexode valve. The triode sections of these two valves are connected to form a relaxation oscillator of the multivibrator type, the time constants of the circuit being such that the frequency of oscillation is 300

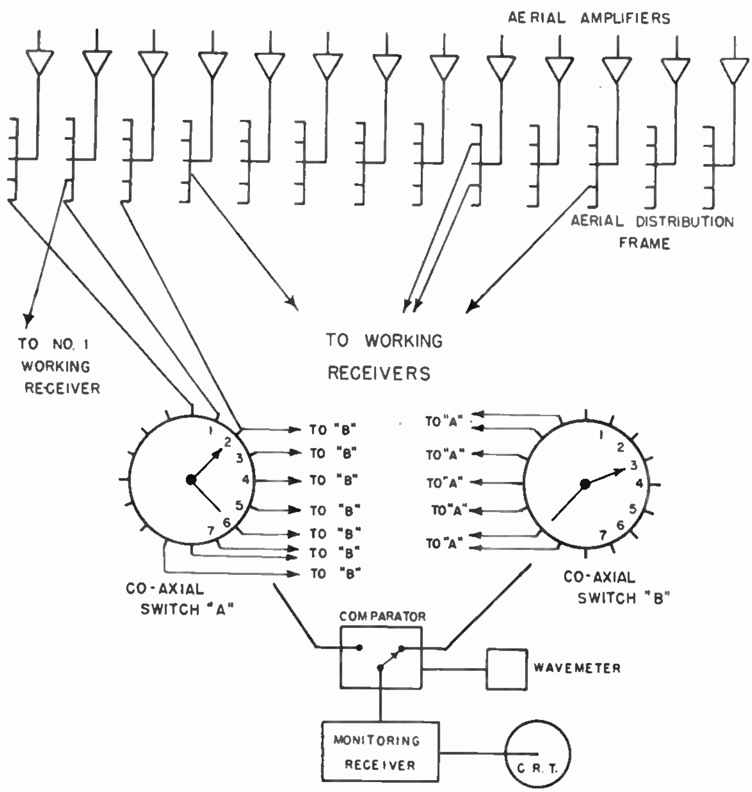


Fig. 1.—Block Diagram of Comparator.

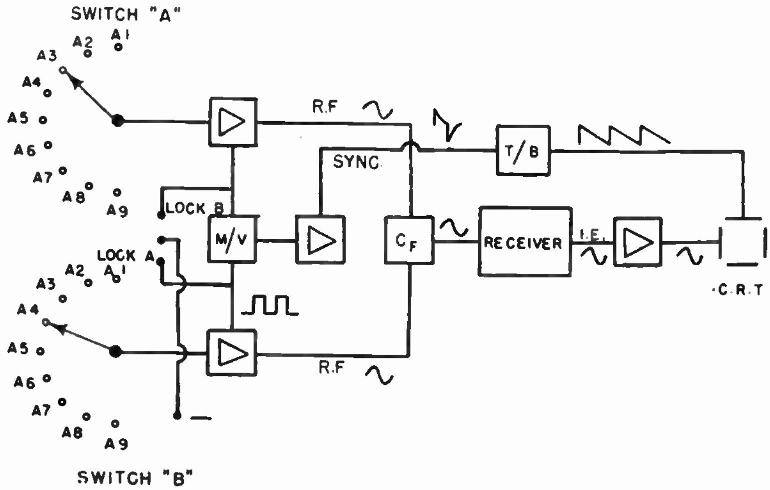


Fig. 2.—Block Schematic of Comparator.

serious distortion of the displayed picture results.

The radio frequency outputs of the two amplifiers are paralleled and fed via a cathode follower stage to the aerial input circuits of the monitoring receiver. The cathode follower provides a convenient method of impedance matching.

The gain frequency characteristic of this circuit must be kept flat within a db or so and the gain of each individual amplifier almost equal over the required range.

Ideally, it is necessary that the comparator shall have zero loss, so that the signals delivered to the aerial input circuits of the monitoring receiver shall be of the same level as those applied to the working receivers. Such a characteristic is difficult to obtain over a wide frequency range, and typical response curves for various values of input equalizer components are shown in Fig. 7. It will be seen that a response within four decibels is obtained over a range of 1-30 Mc/s—curve 1—and if a greater loss is tolerated a response within two decibels is obtained—curve 2. The insertion of a grounded grid pre-amplifier in each input circuit would enable an overall gain to be obtained, if required, but a loss of 2 db was not considered objectionable.

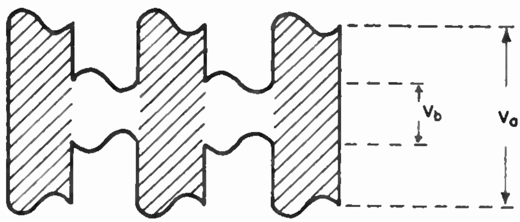


Fig. 3.—Square wave modulation by switching unequal signals.

cycles per second. This frequency was chosen as being suitable for comparing average speed telegraphic signals, but may be increased where very high speed transmissions are being viewed.

The grid of each multivibrator triode is connected to the third grid of the hexode section of the valve ; the change of volts occurring at this point as a result of the square wave oscillation of the multivibrator is sufficient to cause the amplifier to conduct or be completely cut off, according to the sign of the voltage change. Thus the hexode to which the positive-going square wave from the multivibrator is applied will be conducting, and at the same time a negative-going square wave will be applied to the other hexode which will be completely cut off. This state of affairs will be reversed at the multivibrator frequency of 300 c/s and so each amplifier will conduct alternately, the period of conductivity being 1/600th of a second, i.e. 1·66 milliseconds.

It was found that the steep wavefronts produced by the multivibrator caused a pulse of very short duration to appear in the output of the comparator, which created a ringing effect in the receiver input circuits and a blip on the screen of the display tube—Fig. 5. In order to eradicate this effect, the multivibrator anodes were decoupled to earth by condensers C_3 and C_4 to give the oscillator waveform an exponential shape, thus removing the very sharp wavefronts —Fig. 6 (*a*). The D.C. waveform of the hexode amplifier suffers slightly—Fig. 6 (*b*)—but no

The cross-talk between the two circuits may be kept below 40 db by careful mechanical and wiring layout, and further, provision is made to balance the characteristics of each circuit within 1 db.

The output of the multivibrator developed across R_2 is differentiated by R_3 and C_1—as the waveform is not square, the process of differentiation will be incomplete (Fig. 6 (*c*))—and applied to the buffer amplifier V_3. The output of

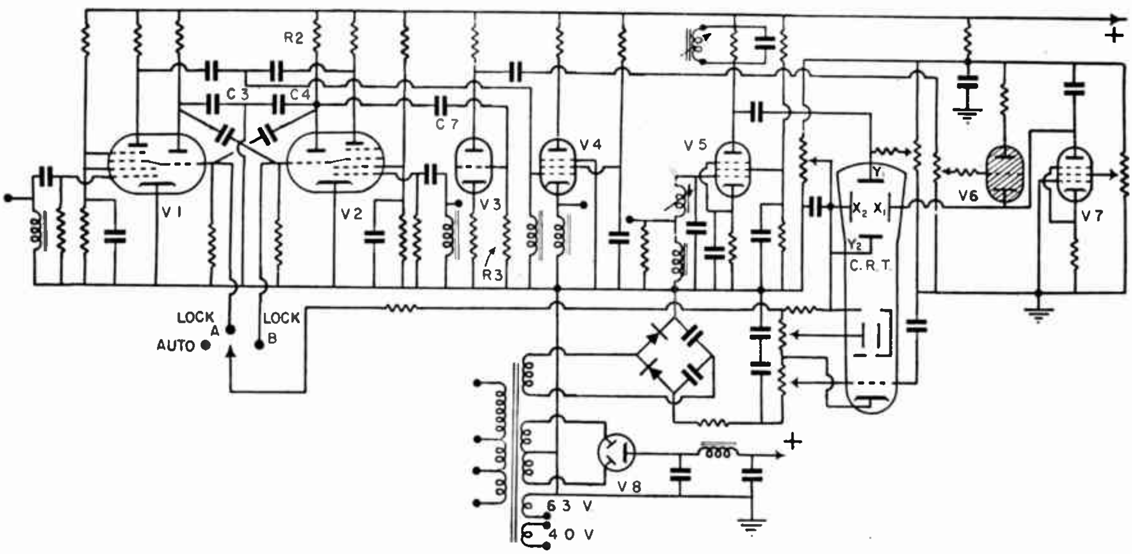


Fig. 4.—Circuit Diagram of Comparator.

this valve is fed to the grid of the thyratron time base valve for synchronization.

An output at intermediate frequency is tapped off from the monitoring receiver and fed via the amplifier V_5 to the Y plates of the cathode ray tube. This amplifier is flatly tuned and has sufficient gain to provide full screen deflection of the 3-in. cathode ray tube before any limiting takes place. A single Y amplifier was found adequate, the amount of trapezium distortion being insufficient to cause any error. No amplitude control is provided on the display unit, as the receiver gain control may be used for this purpose.

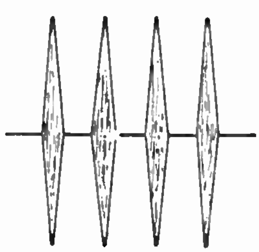


Fig. 5. — Ringing effect of steep wave-fronts.

A linear time base is applied to the X plates of the cathode ray tube, the sawtooth waveform being obtained by a conventional thyratron oscillator circuit—V_6—and constant current charging valve—V_7. The time base frequency may be varied from 2-300 c/s, thus enabling satisfactory monitoring either of a particular signal from one fixed aerial, or the difference in signal between two aerials switched at 300 c/s.

3.0. The Coaxial Switch

The main feature of the design of the coaxial switch is that the cross-talk between each aerial applied to the switch must be reduced to a minimum, otherwise false readings will be obtained when two aerials are compared on the comparator. Fig. 8 (*a*), (*b*), and (*c*) show front, rear and internal views of the switch and it will be noted that a " cartwheel " screen is employed.

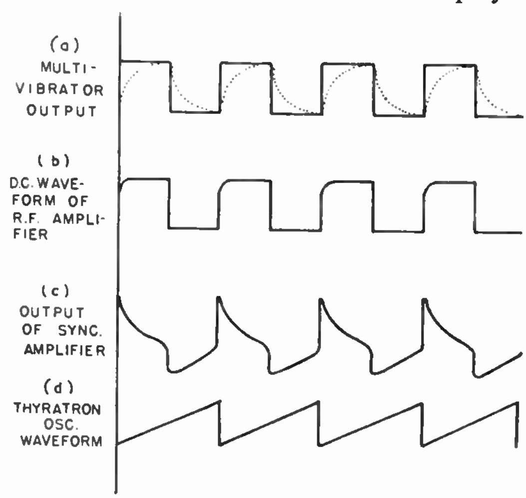


Fig. 6.—Circuit waveforms.

The switch contacts are widely spaced and every other one is earthed and connected to the screen. The whole assembly is of plated brass, the aerial inputs and outputs being fed via coaxial plugs and sockets. The wiper arm is of laminated brass strip and shortest possible length. Between any two aerial inputs, the measured cross-talk was of the order of 45 db, and under these conditions no trouble was experienced.

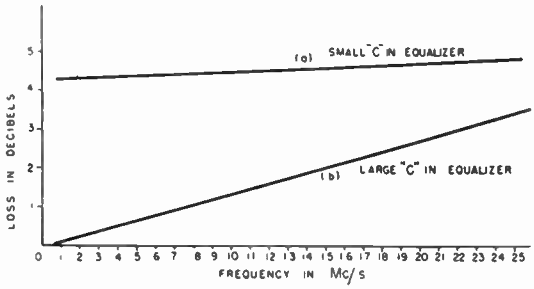


Fig. 7.—Typical Frequency response curves.

4.0. Performance

A series of typical displays are shown in Fig. 9; they are produced by the following conditions :—

4.1.

Fig. 9 (*a*) shows the display obtained with comparator switching automatically, and having no aerial fed to one input from the coaxial switch, and an aerial fed to the other input with no signals present at the frequency to which the monitor receiver is tuned. The picture therefore consists of a period during which receiver noise or "grass" is displayed, and then a period during which noise produced by both the aerial and the receiver is displayed. Sharp noise transients such as those produced by sparking plugs are shown appearing at X and Y : it will be noted that as this noise is appearing only during the period when an aerial is connected it is obviously radiated interference and not mains borne. The gain available is such that this " grass " level may be made to fill the whole screen. It will be noted that a direct comparison between local and aerial borne noise may be obtained.

4.2.

In Fig. 9 (*b*) is shown the display obtained when either one aerial only is fed to the monitor receiver, or when two aerials are applied and a signal is only developed on one of them. The signal is a continuous carrier having a low percentage audio modulation present. The comparator is automatically switching and the time base is adjusted to half the switching speed in order to give two picture cycles.

4.3.

Fig. 9 (*c*) shows the display obtained when two aerials are fed to the comparator which is again in the auto switch position. Some signal is obtained from each aerial, but a greater signal from one than the other. In order to distinguish which signal is fed from the appropriate coaxial switch, it is necessary to adjust either switch, and note which aerial display is effected. Alternatively the switching multivibrator may be made asymmetrical so that the period of conductivity for the aerial signals fed via coaxial

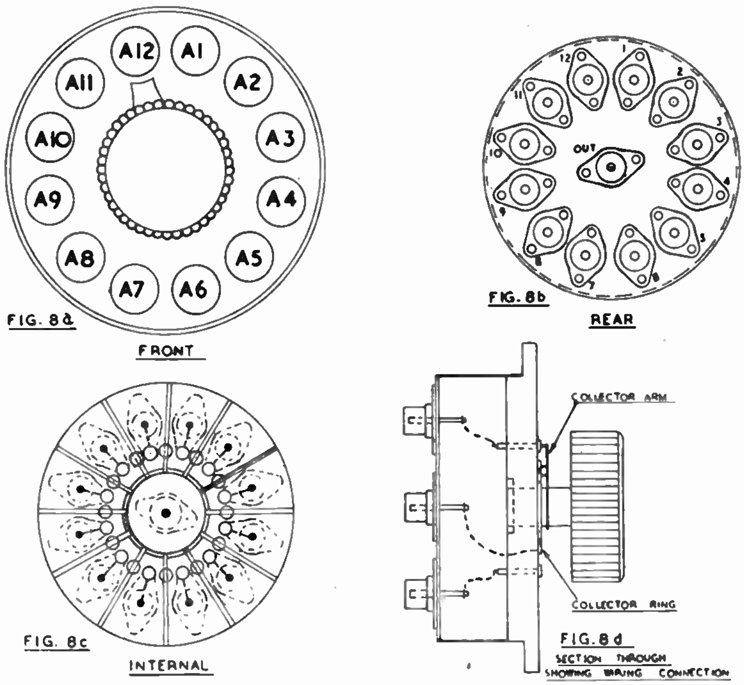


Fig. 8.—Construction of the coaxial switch.

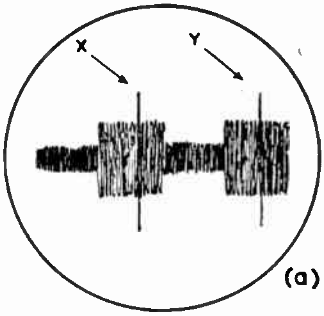


Fig. 9a. — Comparator auto switching : one aerial only applied.

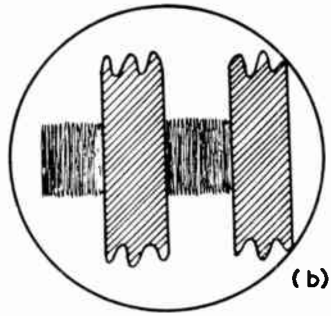


Fig. 9b. — Comparator auto switching ; one aerial only applied : modulated C.W. only present on one aerial.

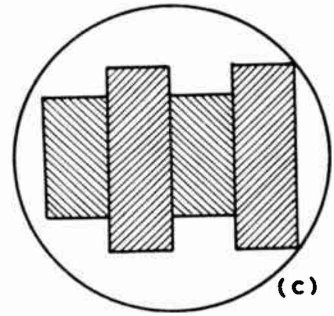


Fig. 9c. — Comparator auto switching : signals applied from two aerials.

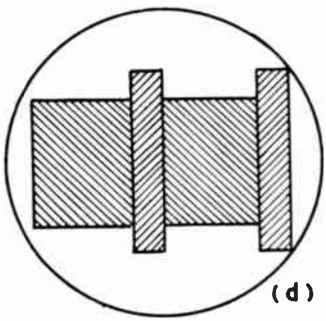


Fig. 9d. — Switching waveform distorted for aerial identification.

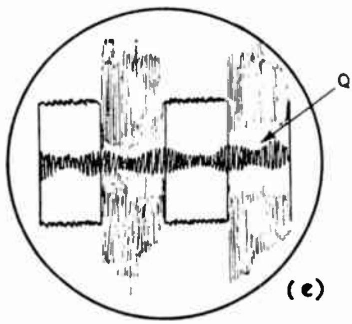


Fig. 9e. — Comparator auto switching. Signals applied from two aerials •having different signal/noise ratios.

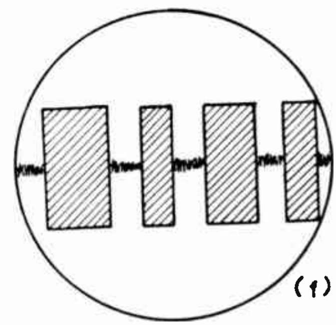


Fig. 9f. — System used for monitoring on/off carrier teleprinter.

switch "A" is larger than that for those fed through switch " B "—Fig. 9 (*d*). If either of those signals is fading, the effect will be a rapid change in picture magnitude for the signals derived from the fading aerial. For best diversity results a pair of aerials should be selected which do not fade simultaneously.

4.4.

The display obtained when the signal from one signal is greater than that from the other, but having a worse signal/noise ratio is shown in Fig. 9 (*e*). In this case the comparator is again switching automatically, the signal applied being an on/off carrier type of transmission. As the carrier is not continually present, a double picture is seen, the smaller trace being the receiver noise level when the transmitter is off. This is shown at point Q. With this type of transmission, it is possible to read directly the signal/noise level at any instant, and to distinguish between noise level and interference level.

4.5.

Fig. 9 (*f*) shows the type of display obtained when the system is used purely for monitoring. The comparator is locked to the coaxial switch "A" and an on/off carrier teleprinter signal is being received. The time base is running at a very slow speed, and the picture may be further expanded to examine individual bauds. All normal monitoring facilities are provided, it being possible to view multipath effect, band shape, noise level, interference, etc.

5.0. Conclusions

The system enables the rapid selection of the most suitable aerials for diversity working. General monitoring facilities are provided from a single control point, without interfering with the working receivers. Instantaneous comparison of signals from any pair of aerials is provided. The signal/noise ratio existing for a transmission on any aerial may be read off directly.

6.0 Acknowledgments

The authors are indebted to M. D. Mason, M.B.E., for his assistance in the preparation of this paper.

TRANSFERS AND ELECTIONS TO MEMBERSHIP

Subsequent to the publication of elections to membership which appeared in the November issue of the Journal, meetings of the Membership Committee were held on December 20th, 1949, and January 10th, 1950. Twenty-six proposals for direct election to Graduate or higher grade of membership were considered, and thirty-one proposals for transfer to Graduate or higher grade of membership.

The following list of elections was approved by the General Council: twenty-one for direct election to Graduate or higher grade of membership, and twenty-three for transfer to Graduate or higher grade of membership.

Direct Election to Associate Member

Astley, Norman Powell, B.Sc.	St. Julious, Malta,
Hosegood, John Massey	Romford, Essex
Martinoff, Matislas	Neuilly Seine, France
Mott, Albert James	Henley-on-Thames, Oxon
Parks, Charles Edward Thomas	Hobart. Tasmania

Direct Election to Companion

Auspitz, John	Pennsylvania, U.S.A.

Direct Election to Associate

Bullough, Weston	Oxford
Du Berger, Paul	Quebec, Canada
Dunn, Gordon Leonard	London, N.W.5
Leeston-Smith, John Michael B.	Daventry, Northants
Levin, Harry	Chingford, Essex
McFee, William Boyd	Macclesfield, Cheshire
MacIntyre, John	Rosyth, Scotland
Neighbour, Kenneth John	Swindon, Wilts.
Notcutt, Stanley Kingsley	London, S.W.2

Direct Election to Graduate

Cameron, Hector Francis L., B.A.(Cantab)	Worcester Park, Surrey
Dunstan, Frank Yeats	Liverpool
Evans, Colin	Bournemouth, Hants
Krishnaswamy, V., B.Sc.	Madras, India
Narasimhan, Venkataramana, M.A., M.Sc.	Tambaram, India
Padmanabhan, Rajagopalachari, M.Sc.	Trichinoply, India

Transfer from Associate Member to Full Member

Lines, Alfred William	Upminster, Essex

Transfer from Associate to Associate Member

Boycott, Douglas Harvey	London, S.W.1
Dovaston, George	London, S.W.2
Whittaker, George William Keeton	Alverstoke, Hants

Transfer from Student to Associate

Boudouris, George	Athens, Greece
Cox, Raymond John, B.Sc.	Wantage, Berks.
Crosoer, Richard Lushington	Sidcup, Kent
Gibbs, Walter Ernest	London, S.W.1
Kerr, James Condor	Blackburry, Lancs.
Leake, Frank Arthur	London, W.6
Paterson, John Lindsay	Nr. Scopwick, Lincs.
Price, Ronald Harry	Swindon, Wilts.
Ramsay, David	Troon, Scotland
Richards, Albert Edward	Heanor, Derbyshire
Tinson, Leonard Percy	Daventry, Northants.
Tomlin, John Frederick	Windsor
Wilson, Samuel Bernard Alexandria	Accra, Gold Coast

Transfer from Student to Graduate

Barnet, Peter Alan	London, W.C.1
Clifton, Frank Ronald	London, W.4
Cunningham, Kenneth William, B.Sc.	Alnmouth, Northumberland
Hilsley, Stanley Philip	Darlington
Krishnamurthi, Mamidipudi	London, W.3
Loh, Kwong Khoon	Penang, Malaya

STUDENTSHIP REGISTRATIONS

In addition to the list of Studentship Registrations published in the November issue of the Journal, 90 studentship proposals were dealt with at the meeting of the Membership Committee held on December 20th, 1949. The following registrations have been approved and include names not published in the December issue.

Killoway, James Malcolm	Sheffield, Yorks.
Krishnan, T. A. Gopala	Madras, India
Krishnamurthi, Mamipudi, B.Sc.(Hons)	London, W.3
Kulkarni Anant Keshav, B.Sc.	Kolhapur India
Kumar, Armit Lal, B.Sc.	Aligarh, India
Kundapurkar, Raghuram U.	Bombay, India
Mansukhani, Harchand, B.Sc.	New Delhi, India
Martindale, James Patrick Alexander, Major B.A.	Worcester
May, Sidney Claude	London, S.E.9
Misra, Awadh Narain	Allahabad U.P., India
Mukherjee, Ram Mohan	Patna, India
Mulchandani, Bhagwan Harumal	Bombay, India
Murzello, Neri	Bombay, India
Narasimhamurti, Chatti Butchi	Coimbatore, India
Navalkar, Moreshwar, P.	Bombay, India
Nehru, Pushkernath, B.Sc.	Kashmir State, India
Nilakantan, Kadayam Ganesh	Bombay, India
Nyayadhish, Vishnu Balkrishna, B.Sc.	Bombay, India
Parekh Bhagvanlal U, B.Sc.	Saurashtra India
Patankar, Atmaram A. B.Sc.	Bombay, India
Pillai, T. N. Damadaram	Tranvancore State, India
Powell, John	Blackpool, Lancs.
Rajput Dattusing Ramsing, B.Sc.(Hons)	Belgaum India
Ramakoteswar Rao, Athuri	Krishna Dt. India
Ramtoola Mohamed Jackaria	Colwyn Bay, N. Wales
Ramuloo, Dhulipudi	Hyderabad, India
Ranga Rao, Katipamula Venkata	Khargpur, India
Rao, B, Siva Nagendra, B,Sc,	Guntur, India
Ramabhadran, Srinivasa, M.Sc.	Bangalore, S. India
Read, Bernard David	Margate, Kent
Roberts, Kenneth Nevil	Wigan, Lancs.
Rodger, John Barclay	Edinburgh
Ronan, Noel	Limerick, Eire
Ross, Norman George	Hampton Hill, Middlesex
Rothenberg, Herman	Johannesburg, S. Africa
Roy, Ranjit Kumar	Karolbagh, India
Shah, Natwarlal Girdharlal	Bombay, India
Shambavi Devi, Mrs. P. S.	Madras, India
Shipgood, Frederick John	N. Shields, Northumb.
Sinclair, Vernon Alban H,	London, W,2
Singh, Pritan Jit, B.Sc.	E. Punjab
Soanes, David	Christchurch, New Zealand
Sobti, Baijnath, B.Sc.	Bombay, India
Sodhi, Giansing, B.A.	Lucknow, India
Srinivas, V. A.	Madras, India
Stepek, Jan Wlawyslaw	Cambuslang, Lanarkshire
Storey, James Sandham	Enfield, Middlesex
Subramanian, Coimbatore, P, B.A.	Bombay, India
Tembe, Shivram Ramchandra	Bombay, India
Tickner, Michael Angus	London, W.13
Tidmarsh, Francis Henry Edgar	Barkingside, Essex
Tolia, Tarachand	Saurastra, India
Tooth, Harvey Sefton	Mold, N. Wales
Toull, Geoffrey Richard	London, S.E.19
Vassilas, Charalambous V	Wembley Middlesex
Venkatraman, Mylapore P.	Bombay, India
Vergis, Minas	Athens, Greece
Vijayaramaraju, P., B.Sc.	Madras, India
Viswanathan, Nairn, B.Sc.	Tranvancore, India
Ward, Derrick Arnott	Beddington, Surrey
Weerasinha, Munasinha A. W.	Moratuwa, Ceylon
Young, Benjamin Lauder	Wembley, Middlesex
Zarbis, Constantin	Athens, Greece

CONTRIBUTIONS

Written comment on papers published in the Journal as well as brief papers are now invited for this section of the Journal. Attention is drawn to the notice under this heading on page 16.

OPERATING CONDITIONS FOR CATHODE COUPLED FLIP-FLOPS

(A contribution suggested by J. D. Storer's paper "A Valve Assisted Filter for Audio Frequencies" published in the July 1949 issue of the Journal)

by

D. W. Thomasson (Associate Member)

The recent paper by J. D. Storer describing yet another application of the cathode-coupled flip-flop circuit has provided a valuable reminder of the versatility of this relatively simple circuit. The writer has used it for seven stages in one piece of equipment, in five of which it generates square pulses, in another is used to obtain a time delay, and in the last produces controlled bursts of oscillation.

The last circuit bears a generic resemblance to that described by Mr. Storer, but with an important difference. The free oscillation condition mentioned by Mr. Storer as undesirable is an essential feature of the preformance of the other circuit. A three-level input signal is applied, and oscillation is obtained when the input voltage is at the middle level (Fig. A).

Now Mr. Storer states that the oscillatory condition only occurs within an input range of 0·1 volt. This remark should be qualified by a statement of the circuit values, since it is quite possible to obtain the oscillations over a much wider range of input voltage. Some general notes on the effects of using different circuit values may be of interest in this, and other, connections.

Considering the circuit of Fig. B, V_1 is cut off when :

$$E_1 < E_b \frac{R_3 - (R_{a2} + R_5)/m}{R_{a2} + R_3 + R_5} \quad \ldots\ldots\ldots(1)$$

$$\text{Where } m = \frac{\text{Anode Voltage on V1}}{\text{Cut off bias of V1}} \simeq 1{\cdot}2/\mu$$

While this condition remains satisfied, the circuit remains quiescent. If E_1 is made positive enough to allow V_1 to pass current, even momentarily, the voltage across V_1 drops, and a negative bias is applied to V_2, aiding the effect of the initial rise in E_i. The action may not be cumulative, however, and triggering will only occur if the circuit is inherently unstable.

The conditions for inherent stability or instability can be expressed in a number of ways. The critical condition defining the border between stability and instability is characterized by equal and opposite changes of anode current, so that the cathode voltage remains constant. This leads to the simplest expression for the border condition. Writing i and e for changes in anode current and anode voltages, with appropriate subscripts :

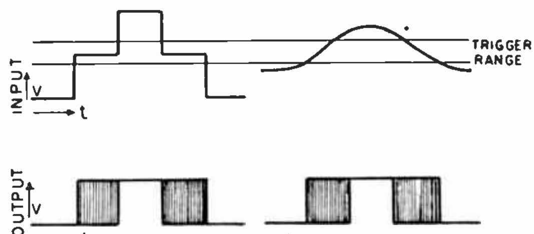


Fig. A.

$$i_2 = g_m \cdot e_1 + \frac{e_2}{R_{a2}} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

But $e_1 = -\, i_1 \,.\, R_2$, and $e_2 = -\, i_2 \,.\, R_5$, whence ;

$$i_2 = -\, i_1 \frac{g_{m1} \,.\, R_{a2} \,.\, R_2}{R_{a2} + R_5} \quad \ldots\ldots\ldots\ldots(3)$$

If i_2 is greater than i_1, the cathode voltage change is in the opposite direction to the input voltage change, and the stage is unstable. The condition for flip-flop action (instability) is thus obtained when :

$$g_{m1} \,.\, R_{a2} \,.\, R_2 > R_{a2} + R_5 \quad \ldots\ldots\ldots\ldots(4)$$

If the above condition is not satisfied, which may occur in a normally unstable circuit if the input voltage is only just positive enough to allow V_1 to pass current, the output is a small positive pulse following the shape of the peak of the input pulse. The circuit, in fact, acts as a stable amplifier.

If, however, the circuit satisfies equation (4), cumulative action drives V_2 beyond cut off, and this condition may persist even when the input voltage is dropped to its original level. In this case, the duration of the condition is determined by the time required for the coupling capacitance C_2 to discharge sufficiently for the bias on V_2 to be reduced below the cut-off value.

If the input voltage is now below the critical trigger level, the circuit reverts rapidly to the original stable state, the increased current in the common cathode resistor biasing V_1 towards cut-off, with a resulting application of further positive bias on V_2. If, on the other hand, the voltage is still above the critical level, the circuit re-triggers at once, and oscillation continues until the input voltage drops below the critical level. If, however, E_1 is applied through a resistance, and is very much more positive than the critical level, the grid of V_1, is held near cathode potential, and cathode current variations will have a relatively small effect on the anode current of V_1. No oscillations then occur.

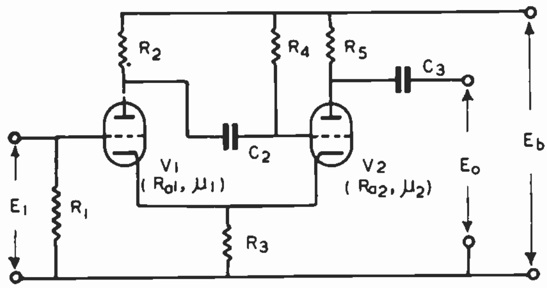


Fig. B.

It is evident that the operation of the circuit depends to a large extent on the relation between the pulse duration and the recovery time of the coupling circuit. A short positive input pulse will give an output pulse of controlled length ; a long input pulse will give a train of output pulses ; and a long output pulse of greater amplitude will produce a long output pulse of the same duration. (See Fig. *C*.)

There are two conditions in which a random output can be obtained. The spurious condition of stability obtained when one of the valves is nearly cut off, and g_m is low, so that equation (4) is not satisfied : and the condition where the input pulse is longer than the recovery time. Mr. Storer appears to refer to the first of these which occurs over a small input voltage range if the condition of instability is only just satisfied in the normal voltage range. It is not, however, a condition of oscillation. That implies instability, whereas this condition is produced by stability. The second condition is a true oscillatory condition, and occurs over an input range of about 10 volts with normal values. It can be avoided by ensuring that the input pulse is short compared with the time constant of the coupling circuit.

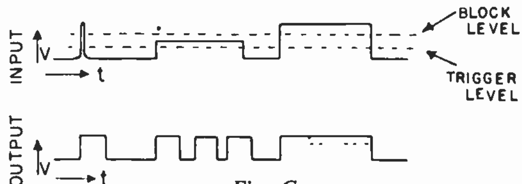


Fig. C.

Like most trigger circuits, the cathode-coupled flip-flop is not really amenable to calculation, owing to extreme grid voltages and the effect of strays. It is hoped that this note has indicated a method of approach which will be of assistance to those faced with the necessity of designing such a circuit.

Reply by J. D. Storer (Graduate)

I find Mr. D. W. Thomasson's detailed analysis of the cathode-coupled flip-flop circuit very interesting. It should be noted, however, that his treatment is concerned entirely with an input of D.C. pulses or square waves, whereas in the valve assisted filter the input consists of a continuous series of sine waves at audio frequencies.

Similarity between the two circuits, and hence input constants, is therefore only apparent if the sine waves are considered to be a train of D.C. square waves of pulse repetition frequency equal to the sine wave frequency.

It would appear that my description of the threshold effect as an oscillatory condition is misleading. In fact the constants of the circuit are such that natural oscillation does not occur, the threshold effect being dependent on a particular condition of input signal during which the circuit acts as a frequency divider, the dividing ratio being dependent on the input condition. Thus if the input signal is gradually raised so that the magnitudes of the sine wave peaks sweep over the critical input level of width approx. 0·1 volt, the circuit will divide at a constantly changing rate until the factor reaches zero and the output pulses have a repetition frequency equal to the sine wave frequency.

When the amplitude of the input sine waves is sufficient to overcome the bias developed across R_3, and also to provide via C_2 an impulse sufficient to cut off V_2, a pulse output will be produced at the input frequency (see Fig. 1). It is possible, however, that while the input level is sufficient to overcome the bias developed across R_3, it is insufficient to cut off V_2. In this case C_2 will be partly charged and a pulse derived from some ensuing sine wave will complete the process of cutting off V_2, with consequent reduction of delay voltage across R_3 during the incidence of the pulse. Thus a pulse output at a lower repetition frequency than the input sine wave, but still dependent upon it, will be produced. The dividing ratio of the circuit of a given input may be adjusted roughly between the limits of 2 and 10 with reasonable stability, but if the level of the input voltage fluctuates and sweeps through the condition of input required for division to take place, then a number of apparently unrelated pulses will appear tn the output. These are described in the text as uncontrolled oscillations.

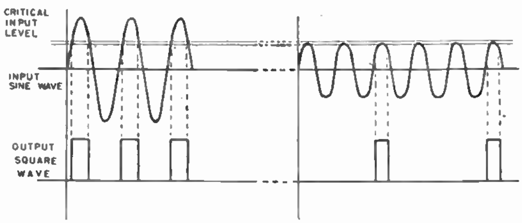


Fig. 1. *Fig. 2.*

The valve assisted filter may be preceded by a similar circuit acting purely as a limiter and having no frequency characteristic, in which case, the level of input to the filter will depend entirely on frequency. Thus frequency division will only occur over a small frequency range at the fringes of the pass band.

A further application of the valve assisted filter not described in the original paper is that it may be used to combine simultaneously the functions of frequency selection and trebling the frequency selected. This may be achieved by feeding the input tuned circuit with a square wave input of frequency of f rich in third harmonics. The input and output tuned circuits are each tuned to 3f. Thus the filter will provide an output at a frequency 3f when the input frequency is f and also of course, unless a trap circuit is included, at an input frequency of 3f.

The applications of the basic circuit described by Mr. Thomasson where the input signals are D.C. pulses, square waves, or stepped waves, are I think fairly well known as they are extensively used in radar and pulse communications equipment. A further application which he has not mentioned and which may be of interest, is the use of a flip-flop circuit whose output frequency varies proportionally to a D.C. input level used for switching diversity aerials to at receiver.

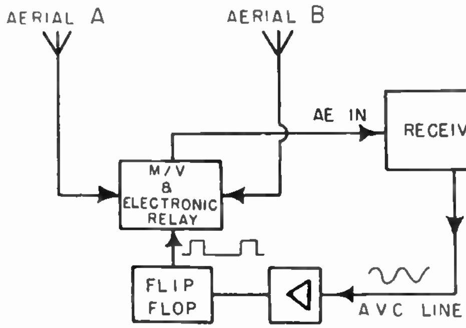


Fig. 3.

Figure 3 shows a block schematic of the system. The A.V.C. voltage from a receiver is fed via a D.C. amplifier to a flip-flop circuit, which is adjusted so that when a high A.V.C. level is present, oscillation does not occur, but as the D.C. input level falls the circuit begins to produce short pulses. These pulses are fed to a multivibrator which will lock on either side. Thus a pulse from the flip-flop will change over the conditions of the multivibrator, and as the pulses are applied to both halves of the multivibrator, a further pulse will again reverse the conducting condition. The multivibrator forms part of an electronic relay connecting either aerial A or aerial B to the receiver, depending on which way it is locked.

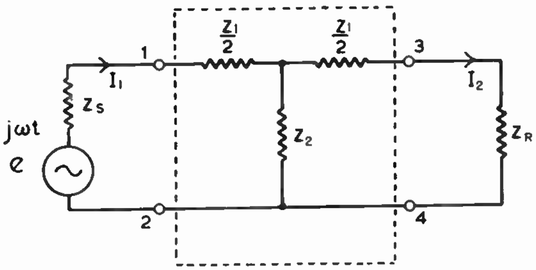
Thus if aerial A is connected to the receiver and the signal produced provides a high A.V.C. level, the electronic relay will remain locked in that condition. Should the signal or aerial A fade, the A.V.C. level will drop, the flip-flop pulses and the electronic relay change over thus connecting up aerial B. If the signal derived from this aerial is sufficient the relay will lock on it, but should it also fade the relay will hunt between aerials A and B, locking on whichever provides the greater signal at any instant.

A NOTE ON FOUR-TERMINAL NETWORKS

by

M. K. Paranjape (Associate)

The usual procedure in the theory of telephone lines, ladder type filters, etc., is to start by considering an infinite line or an infinite ladder and thence to explain the ideas of a progressive wave (of current or e.m.f.), a reflected wave, and how a proper termination prevents reflection and so on. In the following analysis it is shown how these ideas of reflection, etc., may be explained with a single section of a 4-terminal net. In this example a single symmetrical T section is employed.



A T section of an impedance net shown in the dotted-square in the figure is considered. The terminals 1, 2 are joined to a generator of internal impedance Z_S and producing an e.m.f. $e^{j\omega t}$.

The terminals 3, 4 are joined to an impedance Z_R. Then it can be easily shown that

$$I_1 = \frac{1}{a} e^{j(\omega t - \theta)}\left(1 + \frac{Z_1}{2Z_2} + \frac{Z_R}{Z_2}\right) \quad \ldots\ldots(1)$$

$$\text{and } I_2 = \frac{1}{a} e^{j(\omega t - \theta)} \quad \ldots\ldots(2)$$

where

$$a e^{j\theta} = \frac{1}{Z_2}\left\{\left(Z_S + \frac{Z_1}{2}\right)\left(Z_2 + \frac{Z_1}{2} + Z_R\right) + Z_2\left(\frac{Z_1}{2} + Z_R\right)\right\}$$

In (1)

$1 + \frac{Z_1}{2Z_2} + \frac{Z_R}{Z_2}$ can be expressed in the form $\cosh(\varphi + j\psi)$ so that equations (1) and (2) may be rewritten as

$$I_1 = \frac{1}{a} e^{j(\omega t - \theta)}\left(\frac{1}{2}e^{\phi + j\psi} + \frac{1}{2}e^{-\phi - j\psi}\right) \quad (3)$$

$$\text{and } I_2 = \frac{1}{a} e^{j(\omega t - \theta)}\left(\frac{1}{2} + \frac{1}{2}\right) \quad \ldots\ldots(4)$$

It is clear from (3) and (4) that I_1 and I_2 are each the sums of two currents such that, in going from left to right, one decreases in amplitude in the ratio e^{ϕ} and in phase by an angle ψ while the other in going from right to left suffers similarly. Thus, there is a forward wave and a reflected wave of current. In general there are some losses in the impedances and so the amplitude decreases as the wave travels forward. Therefore the direction in which the amplitude decreases is taken as the direction of propagation of the wave. Since e^{ϕ} is positive, the 1st terms on the r.h.s. of (3) and (4) give a forward wave (i.e. left to right) and the 2nd terms on r.h.s. of (3) and (4) give the reflected wave (i.e. from right to left)

Reverting to (1). Suppose now that we write

$$1 + \frac{Z_1}{2Z_2} = \cosh(\alpha + j\beta)$$

If then Z_R is such that

$$\frac{Z_R}{Z_2} = \sinh(\alpha + j\beta)$$

then (1) and (2) can be written

$$I_1 = \frac{1}{a} e^{j(\omega t - \theta)} e^{\alpha + j\beta}$$

$$I_2 = \frac{1}{a} e^{j(\omega t - \theta)}$$

so that there is only the direct wave from left to right with attenuation e^{α} and phase shift β. Thus, reflection vanishes if

$$\frac{Z_R}{Z_2} = \sinh(\alpha + j\beta) = \sqrt{\cosh^2(\alpha + j\beta) - 1}$$

$$= \sqrt{\left(1 + \frac{Z_1}{2Z_2}\right)^2 - 1}$$

i.e. if

$$Z_R = \sqrt{Z_1 Z_2\left(1 + \frac{Z_1}{4Z_2}\right)}$$

This last equation gives the value of Z_R for no reflection.

NOTICES

Honours

It has recently been announced that Mr. Pierre Giroud (Member) has been nominated a Chevalier de la Legion d'Honneur by the President of France for his services in the development of radio equipment for aircraft, especially navigational radio aids. He was also awarded the Medaille de l'Aeronautique by the Secretaire d'Etat aux Forces Armies (Air).

Convention on Radio-Physics Measurements

A two-day Convention on Radio-Physics Measurements, with special reference to local conditions, will be held at the University of Malaya, Singapore, on February 17th and 18th, 1950.

A programme of lectures, discussions and demonstrations will be arranged, under the following general headings :—

(*a*) Basic Measurement Techniques.

(*b*) Measurements under Tropical Climatic Conditions.

(*c*) Standards and Sub-standards available in Malaya, and Co-operation between Interested Bodies.

It is being organized by M. S. Alexander, Professor of Physics at the University to whom any enquiries should be made.

Royal Statistical Society

A provisional group of the Industrial Applications Section of the Royal Statistical Society has been successfully operating in South Wales, and meetings have been held in Crumlin, Cardiff and Swansea during the last year. A formal group to be called the South Wales Group has now been inaugurated under the Chairmanship of Dr. T. V. Starkey of the Technical College of Monmouthshire.

The Section is concerned with the application of statistical techniques to all aspects of industry, including industrial research, development, manufacture and inspection.

Visitors are cordially invited to attend meetings of this and other sections and further information can be obtained from Miss J. Keen, G.E.C. Research Labs., Wembley, Middlesex.

Obituaries

Council regrets to record the death of Frank Herbert ALSTON (Associate Member) of Sheldon, Birmingham, at the age of 46 years.

Subsequent to employment as Assistant Science Master at the King Edward Grammar School, Birmingham, Mr. Alston entered the radio industry in 1925 and was elected an Associate of the Institution in August, 1932. Later, he entered his father's business and at the time of his death was Managing Director of that business.

Mr. Alston joined the Committee of the Midlands Section of the Institution in 1944, and until his death continued to assist the South Midlands Section Committee.

Council also records with regret the death of Mr. Thomas Fearnley ADAMSON, of Southport, Lancashire, who was registered as a Student member of the Institution in 1946.

After serving as a radio officer in the Merchant Navy during the war, Mr. Adamson obtained the Ordinary National Certificate in Electrical Engineering and then joined the International Marine Radio Company Ltd. He made his first attempt at the Graduateship Examination eighteen months ago. Mr. Adamson died after a short illness.

Short Contributions to the Journal

The Papers Committee appreciates that many members are in a position to offer contributions to the Journal, but that such material may not be sufficient to form a complete paper. The Committee, therefore, invites members to submit such articles, which are of the required technical standard, but cannot be classified as complete papers.

It is hoped that these contributions will become a regular feature of the Journal which, in this issue, are on pages 12 to 15.

Binding of Journals

The index inserted in this Journal completes Volume 9 (1949). Members who require the Journals bound are asked to send their copies of the Journal to the Librarian, 9 Bedford Square, London, W.C.1. A charge of 12s. 6d. is made for binding,

NOTICES ON TELEVISION DEVELOPMENT

Television in The Western Union

Within the framework of the Brussels Treaty Organization, television and cultural experts of Belgium, France, the Netherlands, Luxembourg and the United Kingdom, met in London on Tuesday and Wednesday, January 10th and 11th, to discuss the difficult problems which have arisen in regard to the unification of the television systems already existing in France and the United Kingdom with those the other Continental Powers are contemplating starting.

The ideal would be to reach a decision on a common definition in order to facilitate the mutual enjoyment of the national programmes of the five countries which have a common civilization and which are linked by special ties as the result of the Brussels Treaty.

The present situation is as follows. Great Britain, for reasons of continuity, has maintained the use of a 405-line system. France carried out studies during the war and decided to establish a television service of 819 lines, while continuing the 450-line broadcasts already in use before 1940. The Netherlands has rejected both the 450-line system as being of an inadequate quality, and the 819-line system, which would not allow the setting-up of a sufficient number of stations to cover the whole country. They appear to prefer a 625-line definition which corresponds to the American definition (525) taking into account the difference in frequency of the contributory networks (60 in America, 50 in Europe).

At the Zurich Conference, France agreed to transform the 450-line broadcasts to 405 lines in order to enable direct exchanges to be made with the United Kingdom. The decision to maintain the old system for at least ten years was confirmed so that the present 20,000 viewers should not be forced to discard their present sets. Further, France confirmed the decision to establish without delay a final network on the 819-line system.

Great Britain confirmed it was intended to continue the 405-line broadcasts for several years. Representatives stated, however, that if an independent choice had to be made, a system of 800 lines at the lowest would be preferred.

The Netherlands, together with the great majority of other countries, including the United States, was in favour of a 625-line system for Europe, on the grounds that the quality of this system would be sufficient and would allow a greater number of broadcasting stations to operate.

The experts recognized that, although the exchanges of television programmes between the five countries could be effective without a common standard of definition, nevertheless, such a common standard would greatly facilitate the full development of these exchanges and would provide other advantages.

The present development of television in France, the Netherlands and Belgium is of such a nature that the difficulties to be overcome and the sacrifices to be made in order to reach agreement on common standards are bound to increase considerably during the coming months.

The meeting expressed the hope that the five countries of the Brussels Treaty will come to an agreement on common standards, and proposed that the next meeting should take place in Paris on February 20th and 21st, 1950.

Television Exhibition for Birmingham

The Radio Industry Council announces that a radio exhibition, with television as the main feature, is to be held at Castle Bromwich, Birmingham, from Wednesday, September 6th, to Saturday, September 16th. As previously stated, there is to be no National Radio Exhibition in London in 1950.

F.C.C. of America

The Institution received last December from the Radio Corporation of America Exhibit No. 209, which was placed before the Federal Communication Commission and contains a complete explanation of the R.C.A. colour television system.

In addition, two papers, prepared by engineers of R.C.A., concerning particular phases of the system have been received.

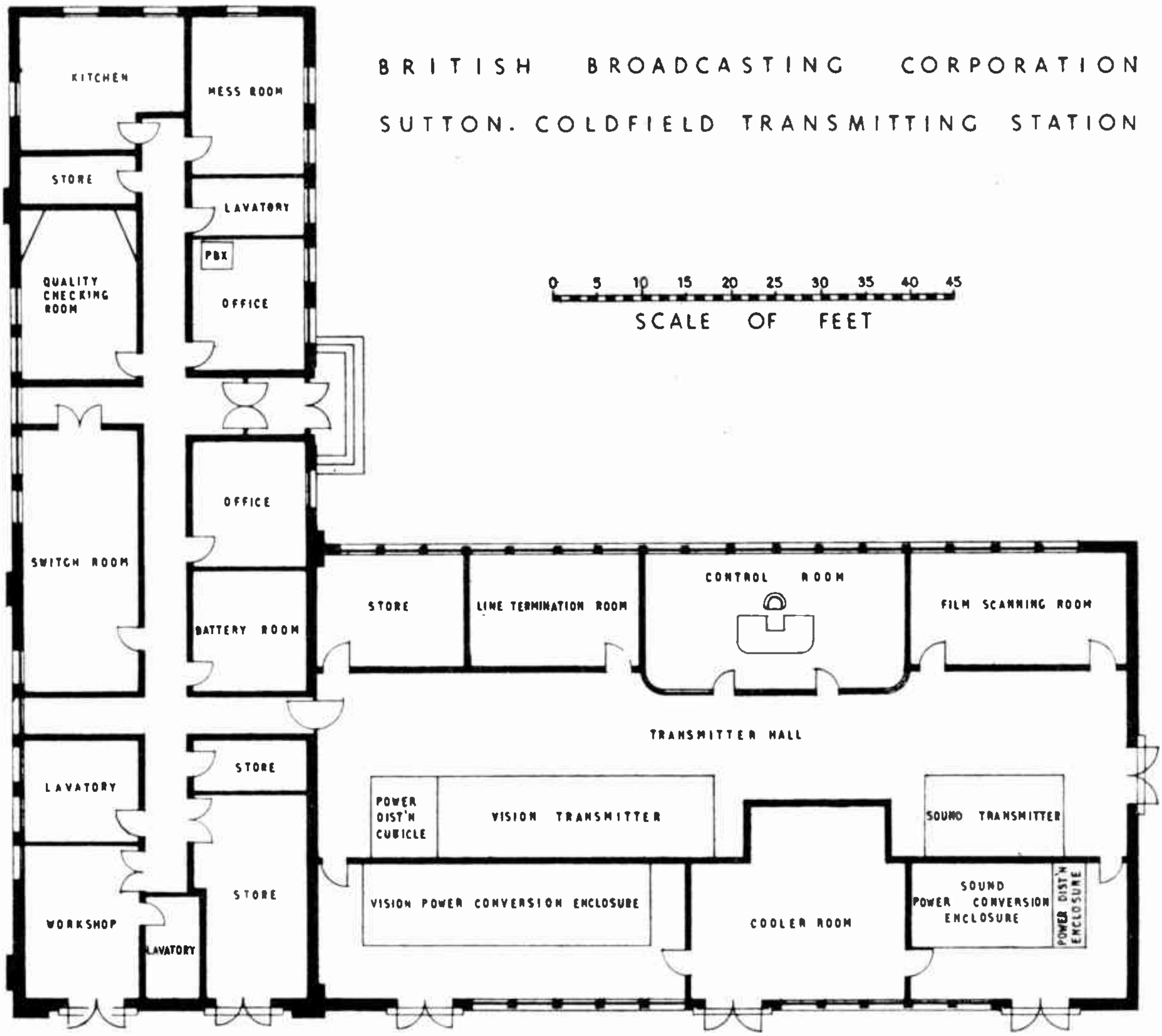
The Papers Committee is at present considering the suitability for publication of these papers in the Journal, and it is hoped to publish them in whole or part in a subsequent issue.

LAYOUT and EQUIPMENT of the MIDLANDS TELEVISION TRANSMITTER

The Sutton Coldfield Television Transmitting Station, the most powerful of its kind in the world, comprises two transmitters, one for vision and one for sound, and a 750-foot mast supporting the aerial. The vision transmitter operates on a carrier frequency of 61·75 Mc/s and its normal peak power output is 35 kilowatts with positive amplitude modulation. The sound transmitter, which is amplitude-modulated, operates on a carrier frequency of 58·25 Mc/s and has a power of 12 kilowatts.

The vision transmitter is the most powerful yet built anywhere in the world. It will work at a peak output power of 35 kW, which is more than double the power of the vision transmitter at Alexandra Palace.

The transmitter has an overall length of 38 ft. and is built in ten cubicles placed side by side. Viewed from the front, the modulator stages



are arranged in order of increasing power from left to right, and the radio-frequency stages from right to left. Thus the modulator output stage is next to the final radio-frequency amplifier.

The modulator has four stages, as follows :—

1. *Pre-amplifier.* This accepts a vision signal having an overall amplitude of 1 volt and a picture : synchronizing-signal ratio of 70 : 30 in terms of amplitude. This ratio can be adjusted in the pre-amplifier, and so can the curvature of the input/output characteristic. Duplicate pre-amplifiers are provided, the change-over from one to the other, in the event of a failure, being made from the control room.
2. *Sub-sub-modulator*, consisting of a single valve amplifier and a cathode follower.
3. *Sub-modulator*, consisting of a two-valve amplifier and a two-valve cathode follower. Between the sub-sub-modulator and the sub-modulator is the " black-level clamp," which keeps the black level, radiated by the transmitter, constant.
4. *Modulator output stage*, consisting of four valves in parallel connected as cathode followers. This stage gives no additional amplification, but provides an output of sufficiently low impedance to supply the heavy grid current, of the order of 7 amperes peak, drawn by the final stage of the radio-frequency amplifier, to which it is directly coupled, plus a large capacitative current, the value of which depends on the picture waveform.

Except for the pre-amplifiers, which use small valves, a single type of forced-air-cooled valve, the ACM3, is used throughout the modulator.

The radio-frequency section of the transmitter is composed as follows :—

1. *Drive unit*, consisting of a precision quartz-crystal oscillator and two stages of multiplication.
2. *Low-power stages*, consisting of a single-valve pentode stage, a push-pull tetrode stage, and a push-pull earthed-grid triode stage, all of which are housed in one cubicle.
3. *Driver stage*, consisting of two ACT26 triode valves in a conventional class-C, push-pull, neutralized, amplifier.
4. *Final modulated output stage*, consisting of two CAT21 triode valves in an earthed-grid, linear, wide-band amplifier, with parallel-line circuit elements. This stage is grid-modulated, and its output is coupled to the feeder through a balance-to-unbalance band-pass circuit.

The valves in the radio-frequency amplifiers are air-cooled except for those in the output stage, which are water-cooled.

A vestigial sideband filter is connected between the output of the vision transmitter and the feeder to the aerial. Its purpose is to give the transmission the asymmetric sideband characteristic that is being adopted for all future BBC television transmitting stations operating in the band 41 Mc/s to 68 Mc/s. The filter, which is of the constant-resistance type, comprises a high-pass and a low-pass section, and is constructed of lengths of concentric feeder mounted on the wall behind the transmitter. The low-pass section is terminated by the feeder leading to the aerial, and the high-pass section by a water-cooled constant-resistance absorber load. The lower-frequency sideband is transmitted fully, but the upper sideband is increasingly attenuated for vision frequencies above 0·75 Mc/s. At 63·25 Mc/s, which will be the carrier frequency of the sound transmission from a future television station, the attenuation introduced by the filter is approximately 12 db.

The sound transmitter has an average carrier power of 12 kW and employs high-power class-B modulation. The drive unit is similar to that for the vision transmitter. The first three radio-frequency stages are push-pull amplifiers, and the output stage consists of a single BR128 valve in an earthed-grid coaxial-type circuit. This stage is anode modulated, and its output is coupled to a second concentric feeder leading to the aerial.

Anode and bias supplies are obtained from rectifiers in the power-conversion plant. All valve filaments are A.C. heated except that in the modulated output stage, which is supplied with D.C. from a motor-generator. The generator has an electronic voltage regulator similar to that associated with the vision transmitter.

All the valves in the sound transmitter are air-cooled.

SOME MECHANICAL ASPECTS OF HERMETICALLY SEALED TRANSFORMER TECHNIQUE*

by

C. Evans† (*Graduate*)

SUMMARY

The paper outlines hermetic sealing practice during 1948. The author records investigations into various properties and phenomona encountered and gives results and conclusions to be drawn therefrom.

TABLE OF CONTENTS

1. Introduction

1.1. *The need for Hermetic Sealing*

The purpose of hermetically sealing a transformer or choke is to enable it to be used in tropical conditions with no danger from extreme climatic variations. It may have to operate at ambient temperatures from −40 deg. C up to 70 deg. C or even 80 deg. C, while humidities may vary from 5 per cent to 100 per cent. It may have to withstand attacks by fungi, exposure to driven rain, salt spray and sand storms.

The conditions for airborne equipment within the European area are scarcely less exacting, for at high altitudes, temperatures approach those of an Arctic winter. (Fig. 1.)

An ordinary dipped transformer is unable to withstand such treatment. The standard tropical test cycle as in K114[1] will render such a component useless in a matter of weeks by reducing its insulation resistance to a relatively low value.[2]

Some method of sealing must be employed which will, as far as possible, exclude climatic variations. This calls for either a metal can, completely sealed, or some form of non-porous cover, e.g. a neoprene sac.

The main problems created by the need for sealed components are; to ensure perfect sealing; to limit the increased overall size of the component; to limit the temperature rise of the transformer and to ensure that excessive pressures are not created within the can due to expansion of the filling medium. The ambient temperature range considered is normally from −40 deg. C to +70 deg. C. Allowing the component a maximum temperature rise of 40 deg. C, gives a possible working range of −40 deg. C to 110 deg. C. External pressures will vary with altitude while the differential pressure within the can may be allowed to approach 20 lb./in.^{2}, but it is usually about 10-15 lb./in.^{2} maximum.

1.2. *Filling Media*

With a sealed container it is possible to surround the transformer with some medium other than air. The only two media worth considering for normal type components are air and oil. The relative merits are, summarizing briefly:

(1) Oil filling will give better cooling, thus allowing the whole component to be made smaller.

(2) The improved dielectric strength of oil means that less space need be allowed for insulation.

(3) An oil leak is detected more readily during service.

(4) An oil-filled component is generally about 15 per cent heavier than if air filled.

(5) Oil filling takes time, requires much complex and expensive plant and could prove a production bottleneck.

(6) An oil-filled component must incorporate some device to compensate for the change

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in volume with change in temperature, which may mean an increase in total volume.

(7) An oil-filled component is therefore, for several reasons, more expensive than an air-filled one.

Normally, therefore, the initial mechanical design is affected by the filling medium to be finally employed and factors (1), (2) and especially (6) should be noted. Where a floating air bubble is used for expansion compensation, the design need not be radically altered.

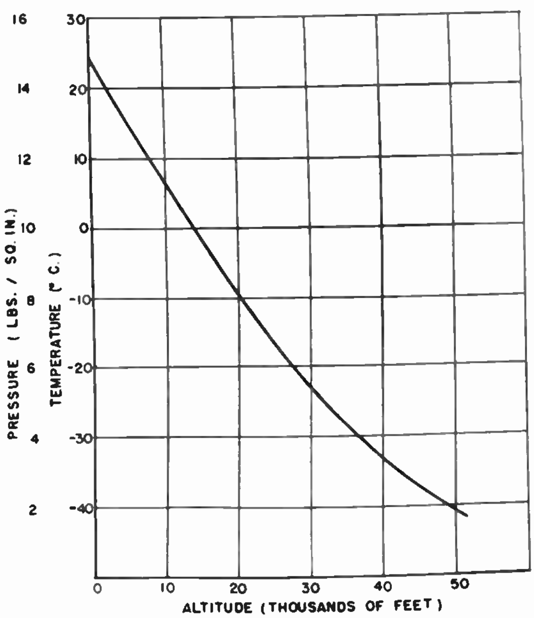


Fig. 1.—Approximate pressure and temperature variation with altitude for an average English day.

2. Sealing and Terminals

2.1. *General*

The two main methods at present in use of effecting an air and oil tight joint are :—

(1) A bond between brass and perbunam with similarly bonded terminals.

(2) A soldered joint, metal to metal with soldered metal to glass or ceramic terminals.

Method 1 is an established practice, and thus generally produces satisfactory sealing. The disadvantages are that the bonding process takes time and calls for very good workmanship. The temperature range of such a component is limited, and mechanically it may have too much flexibility to withstand arduous service use.

In Method 2, the production time for sealing is very short, temperature range is not limited, workmanship may be less exacting and the product is more robust. Disadvantages are that expansion compensation required and, possibly, in obtaining perfect sealing around the terminals. It is noted too that glass seals have a poor response to drop tests, and general rough treatment.

Bonding technique is dealt with fairly adequately elsewhere, so this section will be confined to the latter method.

2.2. *The Container*

Generally speaking, the container will consist of a drawn can with a separate lid taking all the stress. Thus the can acts merely as a cover. With a drawn can there should be no sealing worries, though several drawn cans tested for leakage have given signs of the metal being porous. Others have shown holes clearly visible to the eye, though this was probably due to poor quality material. Where a drawn can is impracticable or for small quantities of pre-production models, a fabricated can with a separate bottom and a seam is required. The bottom will be simply a flat plate with flanges, soldered onto the sides of the can. Whether the flange should fit inside or outside the can is debatable ; from internal pressure considerations there is no difference, the pressures being too small. For sealing properties, the inside fit is probably a little better, though for production an outside fit may be easier. An inside fit decreases the overall dimensions a little and also gives the component a better appearance.

There is no ideal shape for the can. A rectangular section with rounded corners is favoured for many types, since it is economical on chassis space and adaptable for internal breather bags. For large power transformers, an octagonal shape can best be used if it is of the free air bubble type, but if breather bags are required then the can must be rectangular. A circular section is not to be recommended except for special purposes, as it is generally wasteful of chassis space and difficult for breather bag accommodation. It is, of course, the best shape for withstanding high differential pressures, but for fairly low temperature rises this is not very important.

The effect of excessive pressures in components having a high oil/air ratio has been investigated and tests were done with different shaped cans when the pressure was approaching its theoretical limit, i.e., when the expansion of the oil had filled the original air space. In practice, such conditions will never be reached. As the pressure tends to rise steeply, it will either create more air space by distorting the can or relieve the pressure by bursting it.

Two representative cans were given the same percentage air space and subjected to the same temperature increase. Attached pressure gauges measured the internal pressure of each. Can A was octagonal with a flat top having an area of about 10 sq. in. Can B was cylindrical with a flat top having an area of about 4 sq. in. Fig. 2 shows the rising pressures until the cans reached bursting point.

It is seen that while both cans have approximately the same bursting pressure, can A, due to the flexibility of its construction could withstand greater temperature rises than the cylindrical type. In both cases the pressure falls below the theoretical value (from Fig. 4) as the cans bend under the pressure. In such cases the temperature rise to be expected would not exceed about 30 deg. C but, due to an electrical or mechanical fault, this may be increased by a factor of two. Hence, unless a strong and heavy case is used, cans with a large oil/air ratio should be designed to have a good degree of flexibility so that they tend to bend rather than burst. To ensure comparable results, the wall thickness should vary with the size of component. It should be thin enough to have some flexibility yet thick enough to withstand general rough handling.

The bursting of a can usually takes the form of one of the soldered seams or joins splitting. The type of seam, when required, need only be of the very simplest pattern, i.e., a butt joint with cover plate. A double rolled join is favoured by some because of its strength and reliability, but it is difficult to make and the success with the simpler type does not warrant a more troublesome method. The two faces should be tinned before finally filling the edges with solder. Soft solder is satisfactory and the can will generally be of brass, or aluminium in the case of lightweight transformers.

2.3. *The Lid*

The lid should wherever possible contain all the terminals, the filling hole and the fixing lugs. Before the component is fastened to the chassis, the lid will have to support the full weight of the transformer, and should, if necessary, be of heavier gauge material than the can. With small cylindrical types though, the lid should be of a fairly light gauge, the two ends being the only expandable parts.

The lid will normally have flayed edges, and the previous remarks covering flanges will apply. If the transformer is fairly heavy, there may be difficulty in retaining an inside fit flange while soldering. Thus, for large transformers, an outside fit is necessary.

The filling hole should consist of a 4 BA hank bush fixed with the bush on the outside and carefully soldered, on the outside only, to ensure proper sealing. Inside the can, the riveted shank should be flush with the inner surface. A hank bush as the filling hole is necessary in order to apply an air pressure test. An ordinary recessed filling hole is unsatisfactory since testing is made difficult and it is impossible to remove all the air from the can during the oil filling cycle.

The fixing lugs should also take the weight of the transformer, thus putting no stress on the container when it is bolted to the chassis.

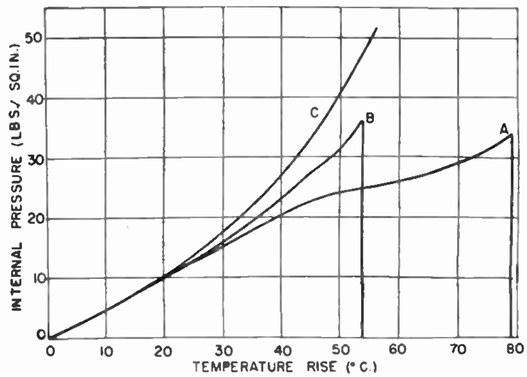


Fig. 2.—Variation of pressure up to bursting point within two sealed cans. (A) an octagonal can, (B) a smaller cylindrical can. In both cases the pressure falls below the theoretical (C) due to bending of the case.

2.4. *Terminals*

Most terminals consist of a lead and an outer ring which is soldered to the main can. These are bonded together with an insulator.

The main types in use are :—

(*a*) A brass-neoprene bond.

(*b*) A silver-ceramic seal.

(*c*) A metal-glass seal.

The simple type of bonded terminal, i.e. a brass wire inserted through a solid neoprene bush gives an excellent seal and none of this type have been known to leak. The neoprene must then be bonded to the main container however, causing difficulties that are explained elsewhere.

Generally speaking, silver ceramic seals are the most satisfactory and are recommended as least likely to give trouble. If desired, the ceramic may be extended to form a top plate which is soldered on to a metal can. Seals have been made combining ceramic with other metals such as platinum and kovar, but little is known about their qualities. The following remarks about glass-metal seals also apply in some degree to ceramic type seals.

Glass/metal types are widely used and should generally give satisfactory results. Difficulties with leaks have been encountered however, and the main problem has been to determine whether the leak is :

(i) Between the metal and glass in the actual terminal, or

(ii) Between the metal of the terminal and the solder attaching it to the main container.

In the former case there is little that can be done except by the manufacturers improving their technique. In the latter case a further field of investigation is opened to find the cause of the imperfect contact.

Of all the sealed components that have been under observation, the majority have leaked oil at high temperature, and careful study has led to the belief that in most cases the leak was of type (ii) above, i.e. due to unsatisfactory soldering. In a number of cases it was difficult to determine where the leak was, but in no case was a leak definitely established to be of type (i), i.e. due to faulty seal manufacture.

It became apparent that the chief difficulty regarding good sealing was the condition of the seals, a large number being dirty and refusing to allow solder to flow. There seemed also to be many with exceptionally poor plating and presenting a surface which would not take solder. It is possible that most leaks were caused by cavities formed by the non-adherence of the solder to the metal and allowing tunnels to stretch from the inside surface of the can to the outside.

The condition of the plating and general finish of the terminals is the concern of the terminal manufacturers and it is essential that no further processing be necessary when they reach the installation stage. No definite reasons are known for the bad finish of the terminals, but it is a point which should be thoroughly investigated in co-ordination with the manufacturer's chemist. It may be that there is a certain deterioration with prolonged shelf life or possibly the particular batches used were of poor quality.

It is not thought that the actual method used to solder the terminal in position should have any effect on the sealing properties, assuming, of course, that reasonable care is taken with every method.

There are various methods which may be used in production to solder the terminals in place. The individual iron or flame method would seem to be too cumbersome and to take too long. Some work has been done on passing heavy currents through the assembly, making it hot enough to melt solder rings placed under the terminals and thus automatically effecting a join. Some success has been achieved with assemblies soldered in this way, but development is required to find optimum working conditions. Other methods suggested are to place the assembly in a hot oven or to pass it through a hot bath. Both oven and bath would, of course, have to be very hot, and the choice of fluid for the bath would be a matter for some research, but this method is believed to have been successful.

3.0 Expansion Compensation

3.1. *General*

There are five principal methods of allowing for oil expansion. They are :—

(1) An air space inside the can or floating air bubble.

(2) Internal sealed breather bags.

(3) Internal breather bags open to the atmosphere.

(4) A case that is self expanding : i.e. a neoprene case.

(5) Metal bellows.

All these methods have been used with varying degrees of success.

Method (1) is the simplest, but cannot be adopted where the oil is used as an insulator and where the component is likely to be airborne, because of the movement of the bubble. Where the oil is used merely as a heat conductor, an air bubble is perfectly satisfactory under all conditions.

Method (2) avoids the limitations of the previous method by preventing the movements of the air. The problems created by the presence of these bags of air in high voltage transformers has been mitigated somewhat by making the bags of some conductive material, i.e. conductive neoprene, which provides an equipotential surface and thus avoids voltage stress across the air. This in turn may increase the insulation problem.

Method (3), if properly designed, has the advantage of developing very little, if any, internal pressure during the expansion of the oil. It has the disadvantage of requiring a seal, or normally two seals, for each bag used. The remarks pertaining to (2) also apply.

Method (4) is probably the best from the compensation point of view, in so far as it creates no insulation or pressure problems. It has disadvantages in other respects however.

Method (5) also creates no insulation or great pressure problems but has the great disadvantages that it may add appreciably to the size of the component, and thus may be unsatisfactory for miniaturized work.

3.2. *Type* (1) *Floating Air Bubble*

The immediate problem presented when considering internal air space types is the volume of air required.

The conflicting factors are (*a*) maximum oil required for good cooling; (*b*) minimum oil required for lightness and ease of expansion compensation. Miniature power transformers should be designed for maximum oil capacity while high voltage transformers, where the oil is required only for insulation, should have minimum oil capacity.

The effect of the oil on the temperature rise of a transformer may be seen from Fig. 3.

Another factor which influences the volume of air is the differential pressure allowable. This is dependent upon the temperature range to which the component will be subjected and upon the temperature of the component when it is sealed.

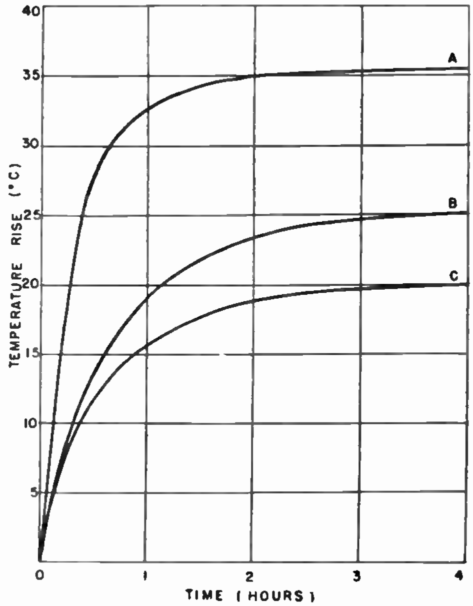


Fig. 3.—Temperature rise of a 30 *VA H.T. transformer sealed in a metal case.* (*A*) *with air filling,* (*B*) *oil filled with* 20 *per cent air space.* (*C*) *oil filled with* 5 *per cent. air space.*

The pressure developed in a sealed container of the free air bubble type may be found by examining the state of the air inside by using the standard gas equation :—

$$\frac{P_i \cdot V_i}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

where P = Absolute pressure
V = Volume of air
T = Absolute temperature

and suffix (i) indicates the condition when sealed, i.e. known conditions and suffix 2 indicates the condition in the state to be examined.

From which,

$$P_2 = \frac{P_i \cdot V_i \cdot T_2}{T_i \cdot V_2}$$

But $V_2 = V_i - q(T_2 - T_i)(V_T - V_i)$

where q = coefficient of expansion of oil

V_T = total space in can not occupied by solids

$$\therefore P_2 = \frac{T_2}{T_i} \frac{V_i P_i}{V_i - q(T_2 - T_i)(V_T - V_i)}$$

$$= \frac{T_2}{T_i} \frac{P_i}{1 - q(T_2 - T_i)\left(\frac{V_T}{V_i} - 1\right)}$$

$$= \frac{T_2}{T_i} \frac{P_i}{1 - q\,t\left(\frac{V_T}{V_i} - 1\right)}$$

where t = change of temperature (note t is negative for decrease of temp.)

$$= \frac{T_2}{T_i} \frac{P_i}{1 - qt\left(\frac{100}{A} - 1\right)} \quad \ldots .(1)$$

where A is the air space expressed as a percentage of the total space.

Figures 4 to 7 show the pressures encountered with varying air space and filling temperature. The temperature range that has been considered for these curves is −40 deg C to 110 deg C, which are likely to be the extreme temperatures encountered by service equipment of the non-silicone variety.

Now from Fig. 4, it is seen that at the upper temperature limit of 110 deg. C the maximum absolute pressures are as shown in Table 1.

Considering the case of a small power transformer when it is desirable to have as much oil as possible in the can, and allowing a maximum absolute pressure of say 26 lb/in^2 it is seen that an air space of 20 per cent is required.

If reference is now made to Fig. 5, it is seen that by sealing the component at 70 deg. C, the maximum pressures have been reduced to those indicated in Table 2.

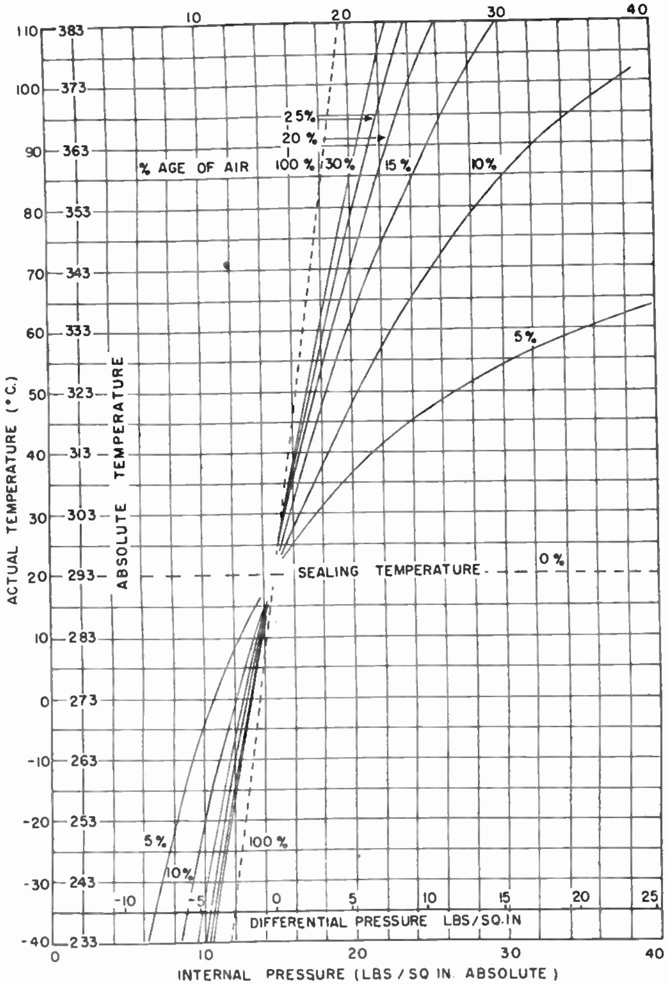
From this it is seen that an air space of only 10 per cent is possible if the component is sealed at 100 deg. C. It is seen from Fig. 6 ;

TABLE 1

% air space	5	10	15	20	25
Abs. pressure	—	40	30	25·8	23·8

TABLE 2

% air space	5	10	15	20	25
Abs. pressure	33	22·2	20	18·8	—



Figs. 4-7.—Theoretical pressures existing within sealed cans containing oil where the air is allowed free expansion and contraction ; and showing how the pressure variation or percentage air space may be reduced to a minimum by suitable choice of sealing temperature.

TABLE 3

% air space	5	10	15	20	25
Abs. pressure	19·2	16·6	16·1	15·7	—

Thus an air space of only 5 per cent is possible. Now, from Fig. 6, at —40 deg. C the differential pressure in the 5 per cent case does not exceed 13 lb/in.², which is by no means excessive but the objection commonly raised to this form of sealing is that the component is always in a state of stress except when working at 100 deg. C, and faults are liable to develop more quickly than if it were sealed at ambient temperatures. When the can is of good design experience has shown that this is unlikely to happen.

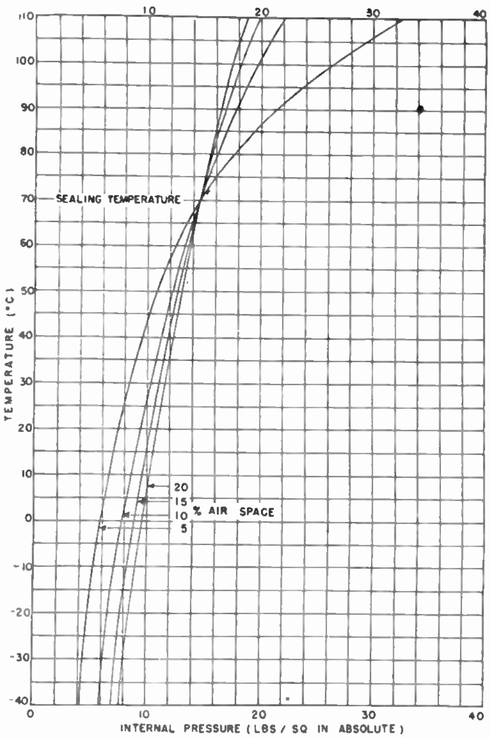


Fig. 5, *see Fig.* 4.

When the maximum permissible pressures are known for both temperature extremes, the percentage air space and the sealing temperature may be found. From equation (1).

$$A = \frac{100\,qt}{1 + qt - \dfrac{T_2 P_i}{T_i P_2}}$$

where $T_2 = 110$ deg. C (383 deg. K)
$T_i =$ filling temperature
$P_i = 14{\cdot}7$ lb/in.² (absolute)
$P_2 = P_{110} =$ allowable pressure at 110 deg. C.

Likewise
$P_2 = P_{-40} =$ allowable pressure at —40 deg. C ($\therefore$ t is $-$ *ve*)

$$\therefore\ A = \frac{100\,qt}{\dfrac{T_2 P_i}{T_i P_2} - 1 + qt}$$

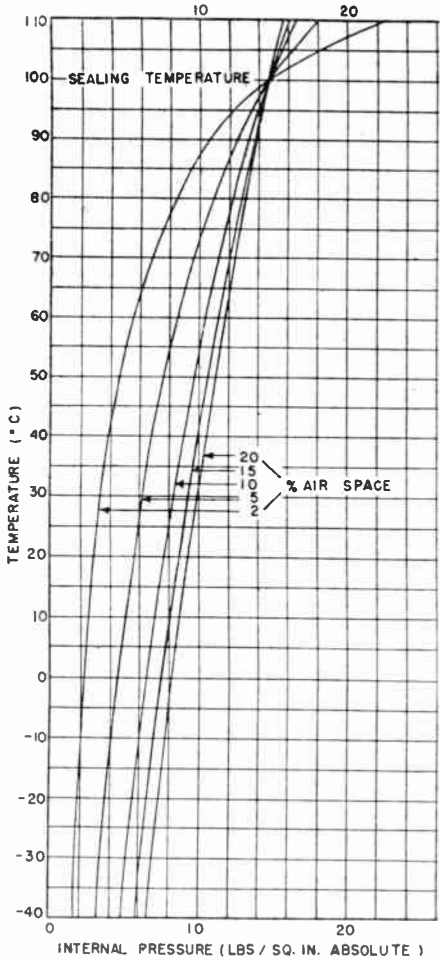


Fig. 6, *see Fig.* 4.

Using these equations Fig. 8 has been plotted for several values of P_{110} and P_{-40}. The intersection of the two permissible pressure lines will give the sealing temperature for the maximum amount of oil.

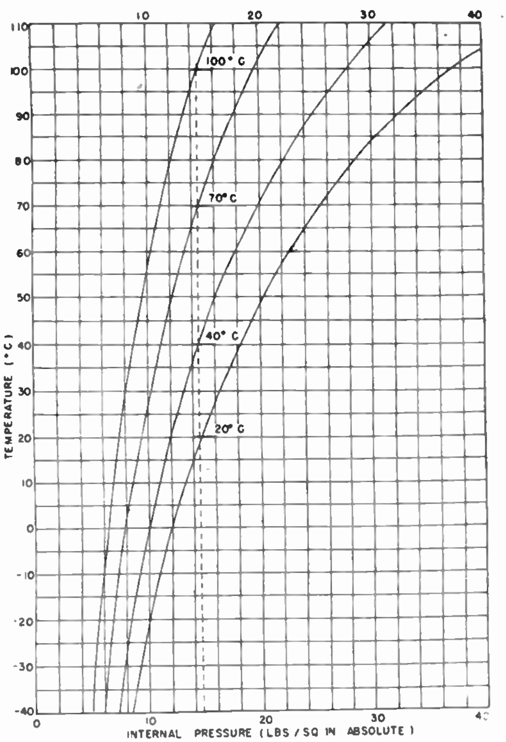


Fig. 7, see Fig. 4.

3.3. *Type 2 Internal Sealed Breather Bags*

There are further difficulties to be considered in the case of components using air sealed breather bags. If the air inside the breather bag could follow the law PV = wRT, then the determination of the percentage air space would be the same as above. As the breather bag material is insufficiently elastic to allow free expansion the expanded volume of the bag is limited to some figure which is less than that theoretically required.

This figure will be called E. Then :—

$$E = \frac{\text{Expanded volume of bag (in vacuo)}}{\text{Original volume of bag}}$$

Now E must be measured for each particular type of bag being considered, as it will obviously vary with the shape when at rest. The method used to determine E, is to immerse the bag in oil in a graduated cylinder, noting the increase in oil level. Allowing for the solid material of the bag, the volume of air can be found. The cylinder is then placed in a vacuum and the new oil-level noted. Hence the expanded volume E can be deduced.

Measurements have been made on several types of breather bags giving the approximate results as below.

TABLE 4

Breather bag (type)	A	B	C	D	E
E	1·7	1·7	1·12	1·1	1·08

It is interesting to compare these values with the theoretical value E_T required for various conditions.

$$E_T = \frac{\text{Air space required at } -40 \text{ deg. C}}{\text{Air space at sealing temperature}}$$

$$= \frac{V_i + qt\,(V_T - V_i)}{V_i}$$

$$= 1 + qt\left(\frac{V_T}{V_i} - 1\right)$$

$$= 1 + qt\left(\frac{100}{A} - 1\right) \quad\ldots\ldots\ldots(2)$$

where A = percentage air space

t = sealing temperature—(—40 deg. C)

Hence substitution of values for A will give corresponding values for E_T.

TABLE 5

Air space	5%	10%	20%	30%
E_T (sealed at 20°C)	1·8	1·38	1·17	1·1
E_T (sealed at 100°C	2·86	1·88	1·37	1·23

For safe usage E should be equal to or greater than E_T otherwise the further expansion required will come from minute particles of air left in the winding, etc. This would mean the creation of high electrical stress points and also the formation of differential pressures possibly approaching 15 lb/in.^{2} This danger obviously does not arise with the floating air bubble type of construction.

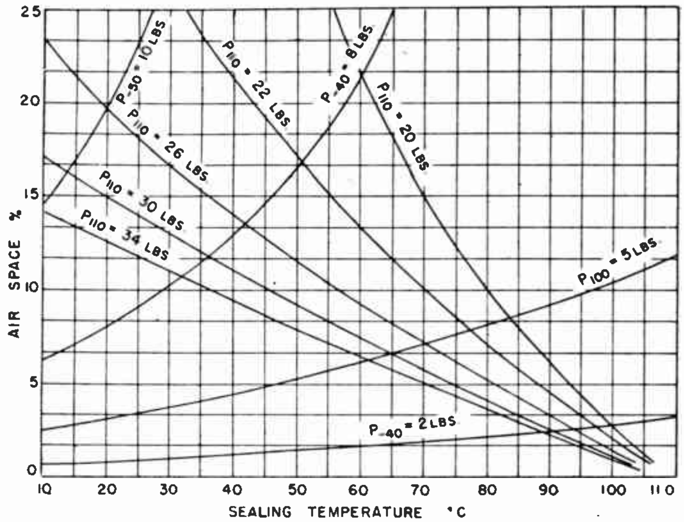


Fig. 8.—The air space and sealing temperature for any given maximum absolute pressure at 110 deg. C (P_{110}) and at −40 deg. C (P_{-40}). The intersection of the two permissible pressure lines gives the sealing temperature and air space.

Note : for P_{100} read P_{110} and P_{-50} read P_{-40}.

From the comparison between the theoretical and actual figures therefore, it is seen that some types of bags are unsatisfactory for normal use, as the law

$$E_T \geqslant E$$

must be true for safe operation.

The bags measured were all made of neoprene and were of various shapes. Types C, D and E, however, were cylindrical in shape. If a hollow sealed body is forced by internal pressure to increase its volume, it will attempt to assume that shape which, with its limited surface area, will enclose the maximum volume, i.e. it will tend to become spherical.

If the body is long compared with its cross-section, however, it will try and assume a cylindrical shape. Therefore, if a long body is of circular cross-section when at rest, in order to enlarge the internal volume, the walls have no alternative but to stretch. But a considerable force is required to stretch a cylinder of neoprene with walls of thickness $\frac{1}{32}$ in. or more, and, from measurements made when applying a high pressure to the interior of a cylindrical bag, it has been concluded that for the pressures met with in transformer work, moulded neoprene can be considered as practically unstretchable.

Some types of cylindrical bag have a hemispherical end, which is undesirable as it is a shape already enclosing maximum volume and thus not allowing for any expansion.

The use of cylindrical bags with walls of only a few thousandths of an inch thick is possible if the bags are dipped instead of moulded. These would open up several desirable possibilities but unfortunately none were available for experiment.

From equation

$$E_T = 1 + qt\left(\frac{100}{A} - 1\right)$$

Fig. 9 has been plotted showing that for small air/oil ratios the increase in space required upon contraction of the oil is considerable.

Now assuming a component with a sealed air bag, E = 1·7. From Fig. 9, we have :—

TABLE 6

Sealing Temp.	20°C	70°C	100°C
Air space	5·7%	10%	12·3%

It is known (from Fig. 4) that sealing at 20 deg. C requires an air space of at least 15 per cent to avoid excessive pressures with an increase of temperature. Substituting therefore :

TABLE 7

Sealing Temp.	20°C	70°C	100°C
Air space	15%	10%	12·3%

If the smallest possible air space is required, it is seen that there is an optimum sealing temperature which will depend upon the E of the bags used and the internal pressure at high temperature to be allowed.

Equation 2 may be expressed as

$$A = \frac{100\,qt}{E - 1 + qt}$$

and for a given value of E, substitution of various values of t will give values for A. This is done to give the E lines of Fig. 12.

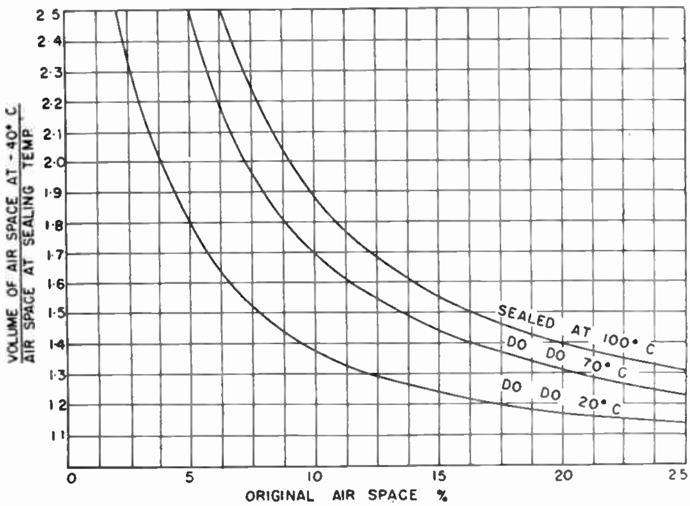


Fig. 9.—Showing how the air space required at low temperatures increases rapidly for originally small air spaces and high sealing temperatures.

As the breather bag prevents free expansion, it also prevents free compression and thus only a portion of the work done by the expanding oil at high temperatures will be used to compress the air, the rest being needed to change the shape of its container. Therefore, to achieve a given decrease in volume of air, the pressure must be greater than if the air is loose in the form of a floating bubble. Consequently the standard curves of internal pressures (Figs. 4-7) do not apply if the air is in some form of bag.

In order that this deviation from the general law may be taken into account, a factor C is introduced :—

$$C = \frac{\text{Compressed volume of bag at max. pressure}}{\text{Original volume of bag}}$$

Now, whereas in the determination of E the vacuum method gives an absolute measure of expansion, the compression ratio will obviously vary with the pressure applied. Results tabulated here were done up to a maximum absolute pressure of 45 lb/in.[2]

The method used to determine C is similar to that used for finding E. A graduated cylinder containing oil is used to indicate volumes and the whole apparatus is subjected to an air pressure.

The laws followed by the PV curves of various bags under compression differ, and thus it is not possible to lay down any general law of behaviour. The simplest method of determining the behaviour of a bag is to subject it to a pressure test and plot a curve similar to the ones plotted for various types of bag in Fig. 10.

These curves are interesting as they illustrate the impracticability of breather bag type E which had been designed and used in all good faith before its incompressibility was realised.

The C factor to be used in calculation is that which corresponds to the maximum allowable pressure. The figures in Table 8 which give results for various bags were taken under isothermal conditions so that under actual working conditions the result would tend to be a little higher in the case of the first two types, but would not, of course, change for the last two, which are open to the atmosphere.

TABLE 8

Breather bag (type)	A	B	C	D	E
C At 30 lb/in² abs.	·646	·67	0	0	·965

The theoretical requirements for

$$C = \frac{\text{Compressed volume of air}}{\text{Original volume of air}}$$

$$= \frac{V_i - qt(V_T - V_i)}{V_i}$$

$$= 1 - qt\left(\frac{100}{A} - 1\right)$$

$$\therefore\ A = \frac{100\,qt}{1 - C + qt} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

which gives for a component sealed at 20 deg. C :

TABLE 9

Air space	15%	20%	30%	40%	50%	60%
C_T	·683	·776	·870	·916	·944	·962

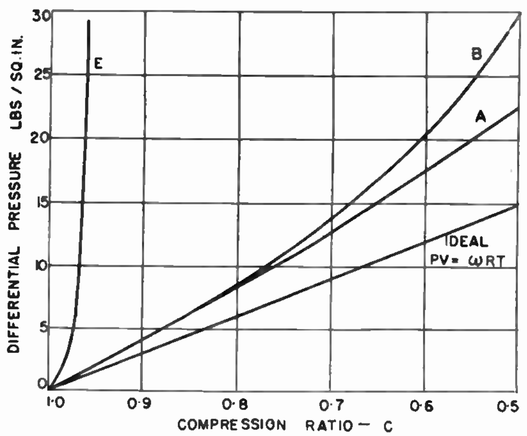


Fig. 10.—Illustrating how the shape of a breather bag determines its compressibility. Types A and B are triangular and type E cylindrical.

This shows that in order to satisfactorily use bag type E, the air space would have to be over 60 per cent.

The various cross sections of the bags measured are shown in Fig. 11 and if they are considered from the point of view of what shape they will assume when pressure is applied either inside or out, it is seen that the triangular bags are superior.

From the definitions of C and C_T, then obviously for safe working

$$C < C_T$$

or expressed in a handier form and knowing C by measurement,

$$A \geqslant \frac{100\,qt}{1 + qt - C}$$

For ease of working therefore, the sealing temperature should be as high as possible which conflicts with the findings regarding the expression ratio E. In order that some satisfactory compromise may be easily reached, the C lines are added to Fig. 12 from equation 3 which may be used to give the optimum sealing temperature and the air space required when both these factors are considered. The use of the curves is quite straightforward. The E and C of the bags to be used are determined experimentally.

Then the intersection of the two lines representing these quantities will give the sealing temperature for the air space indicated. As will be appreciated, if the intersection of the actual conditions in use comes within the lower quadrant formed by the theoretical curves, then there will be excessive pressures at high temperatures and voids formed at low temperatures. In the left hand quadrant there will be the former fault only, and in the right hand quadrant the latter. The higher the point in the top quadrant the larger the safety factor, but the greater the air space required and the less oil there need be.

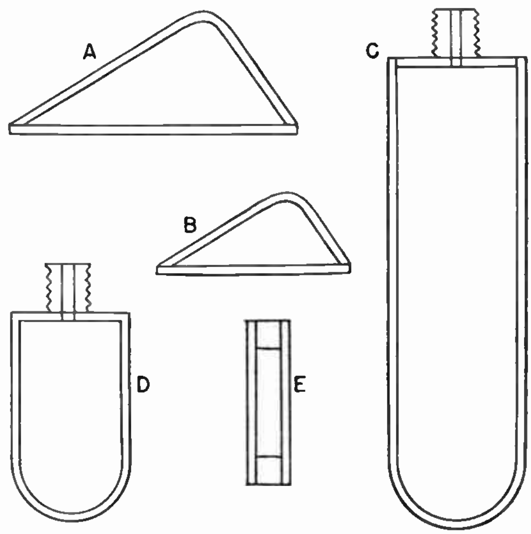


Fig. 11.—Cross sections of various neoprene breather bags experimented with.

3.4. *Type 3 Sealed Breather Bags Open to the Atmosphere*

The problems of air space and sealing temperatures for components using open type breather bags are less difficult than for types with closed bags due to lack of pressure at high temperatures. The low temperature problem has still to be considered, though, and should be dealt with as for type 2. With properly designed bags it is possible to have a very small air space. In determining the air space and sealing temperature to be used, the E of the bag should be found experimentally.

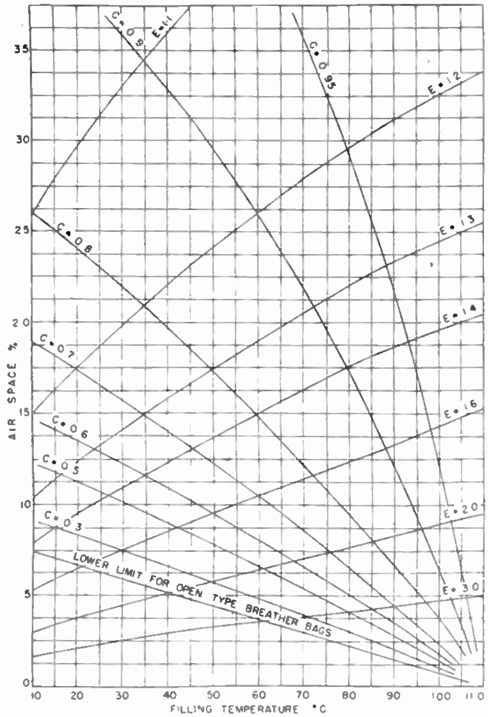


Fig. 12.—Chart for determining the sealing temperature and air space for any component employing either open or sealed breather bags.

This is slightly more complicated than when measuring closed bags. Because of the low E of this type of bag already in use it is quite safe to seal the end and perform the test as before. If, an open bag with a large E is being considered, the orifice must be free at atmospheric pressure while a vacuum is drawn around the rest of the bag. When E has been found, then Fig. 12 should be consulted, ignoring the C lines. For maximum oil, the sealing temperature should be as low as possible, but on no account should the sealing point be below the line marked "Lower limit for open type breather bags." This line shows where, at the particular sealing temperature and air space, the expansion of the oil would equal the original air space at high temperatures.

This assumes that the bag is completely collapsible when subjected to external pressure.

3.5 *Types* 4 *and* 5 (*No Air Space*)

With the metal bellows type, it is important to know the force required to extend or contract the bellows. This force will then be the internal pressure developed, and it must not exceed the pressure limits to be conformed to. The amount of expansion or contraction required from the bellows is the same as that of the oil, and will depend upon the sealing temperature. The neoprene case type should present no difficulty, readily contracting and expanding, though the E and C constants of the cylindrical types should be checked since they have similar properties to cylindrical breather bags. They also have certain undesirable characteristics at —40 deg. C.

3.6. *Properties of neoprene when used for breather bags.*

The main relevant properties are the E and C values, but when neoprene is used as the expendable material, the above calculations regarding the value of E at low pressures may have to be modified in view of the low temperatures accompanying such a change. Strictly the above theory is acceptable only for bags of material which remains completely pliable at all temperatures being considered, such as Silastic (silicone rubber) or certain high pliability neoprenes.

Ordinary neoprene is not very satisfactory in this respect as it becomes hard as the temperature is reduced.

From Table 10 it is seen that a bag may not respond to a pressure of 15 lb/in.^{2} (the maximum possible) after it has reached, say, — 30 deg. C. Thus for the remaining 10 deg. C down to —40 deg. C, there will be oil contraction but no compensating expansion by the bag. Hence voids will be formed.

All neoprene bags have some bonded part, and thus their working temperature must not exceed that which is sufficient to damage the bonding solution. In normal cases, this is about 110 deg. C. There have been no cases of bags being damaged at temperatures lower than 105 deg. C.

TABLE 10

Temperature	Condition of Neoprene
−14°C	Hardening, but still pliable to normal pressures
−28°C	Harder, may not respond to low pressure changes
−36°C	Harder, but can be bent with finger pressure
−40°C	Brittle. May be cracked with light blow

Bags of silastic will withstand temperatures up to 260 deg. C without damage. Several bags were found during investigation to have small leaks which in the main originated from the bonded surfaces. The dangers of the bursting or leaking of a breather bag while in service may be severe and it would appear imperative that all bags be given some test for sealing other than visual inspection.

The best method of testing completely sealed bags is to employ the vacuum test as in 4.3. They must be held under oil or water while the vacuum is pumped. A pressure of about 10 mm mercury should be sufficiently low to show leaks. Once this pressure is reached it is held for 2 minutes and then released. Care should be taken to distinguish between air from a leak and air being released from adhesion to the surface or rough edges. Most of this latter air may be removed by rubbing the surface when under oil or by brushing the rough surfaces with a stiff brush which is free from air.

For open type bags, the procedure is slightly different. The end could be sealed up and the test done as before but it may be quicker to use some other method. The only other test that has been used is to inject air at pressure into the bag which is dipped in oil for about 1 minute. With bags of normal wall thickness, a pressure of about 40 lb/in.^{2} should be sufficient but, if much thinner bags are used, then this must be reduced. The choice of test will rely chiefly on its expedience in being able to test production quantities.

4. Testing of Sealed Components

4.1. The testing of sealed components falls roughly into two sections; the testing of the electrical properties and the testing of the mechanical properties.

4.2. *Electrical Testing*

While this is beyond the scope of the present report, it is worth bearing in mind that, even with experimental models, testing should be thorough before the sealing of the component, since the unsealing of a can is an untidy, lengthy and damaging process. Therefore, as well as preliminary testing to see whether the component is satisfactory, there should be another testing cycle immediately before it is sealed in the can to account for any possible errors introduced in fastening on the lid, soldering to terminals, etc.

4.3. *Mechanical Testing*

The main test under this heading is to determine the condition of the sealing. The criteria of good sealing are:

(1) That no oil shall be able to get out;

and (2) that no air shall get in.

While it is very difficult to determine whether air does get in (and it is difficult to prevent minute quantities of air actually passing through the seals) it is thought that if a small leak does exist, but is not large enough to pass oil, then in those conditions which are most favourable to its escape, the amount of air which will be able to pass through the leak will be quite negligible.

Although theoretically such a component is not hermetically sealed, perfect sealing is so difficult and such a rarity that, to allow no tolerance, would make production a practical impossibility.

There are three items which may give leakage trouble. These are the can, the lid and the terminals, and, of course, the junction of any two of these. The various tests that may be applied are:—

Visual inspection

Most of the major leaks may be found by careful scrutiny of the various parts. This is particularly the case with the can, which has only plain soldered seams as possible leakage places. There should be a smooth surface of solder at all joints and seams, and no crevasses or pin-holes should be allowed. This will also apply to the soldering of the terminals and fixing the lugs onto the lid. A lid with pin-holes around these parts may or may not leak, but, for safety, it is advisable that no pin-holes should be allowed to pass inspection.

Oil Leakage Check

This is one of the critical tests of the component. The usual method of carrying it out is to place the component in an oven and heat it for, say, six hours at a temperature of about 100 deg. C, or possibly 105 deg. C. It is advisable that the component be moved during this test, i.e. turned upside down, so that the oil is given every opportunity to find leaks. This test has the obvious disadvantages that it takes such a long time and that the component must be quite finished before it can be done. Hence if a leak is found at this stage, it is practically impossible to repair it. Thus while this method should be used for stringent testing of development models, it should not be used for routine testing. As yet no absolute test has been devised to check the intake of air through leaks.

Vacuum Tests

This test was used as a rapid alternative method of finding leaks. It should be done preferably before the component is oil filled. The component is immersed in oil (or any liquid) and placed in a vacuum chamber, which is then evacuated.

There will then be a differential pressure approaching 15 lb/in.^{2} between the interior and exterior of the can. Thus air will be forced through any leak which may be there. This method has the additional advantage that air bubbles passing through the oil are, owing to the low pressure, automatically enlarged. Thus with the small vacuum tank used for the experiments, giving pressures of about 7 mm mercury, an air bubble was about 100 times larger than it would be at atmospheric pressure.

In practice, however, it was this ultra sensitive response which rendered the test useless. Minute cavities, rough surfaces, specks of impurities, etc., anything to which air could cling would all emit quantities of bubbles possibly for several hours. Where there was a definite leak, of course, there would be a continuous rush of bubbles, but some terminals would also emit small bubbles even when the oven test as above, had failed to show a leak. This could have been due to cavities or other air locks in or around the terminal or close to leaks too small to pass oil but sufficiently large to allow microscopic quantities of air to be forced out.

Thus, as a method of definitely determining whether a component would leak oil or not, the test was a failure. Various tests were tried with reduced differential pressure, but the bubbles merely became smaller and their progress through the oil slower. Hence these results were even more inconclusive.

Air Pressure Test

This test has, up to the present, given the most satisfactory results. It consists merely of injecting through a Schreider valve, screwed into the component, air at high pressure. The whole component is then immersed in oil (or water) and the air inside has sufficient pressure to force its way through any leak which is large enough to allow the oil to pass through.

There are, however, several points to consider. In some cases air injected at 20 lb/in.^{2} has been insufficient to give positive indication of all oil leaks. Thus pressures of 40 lb/in.^{2} and sometimes 60 lb/in.^{2} have been used. But with pressures of this order there is the obvious danger of distorting the can or even perhaps bursting it. Again, high pressures may be damaging to glass seals and may possibly fracture them, or they may fracture due to distortion of the lid.

It is difficult to lay down any specific pressure that should be used, but it will probably be of the order of 40 lb/in.^{2} Certainly it should be more than 20 lb/in.^{2}

4.4. *Testing Procedure*

It is essential of course that each component is tested for sealing properties before it is finally assembled and soldered up.

It would be possible to test each individual terminal before soldering in position, but although this need only take a few seconds, the number of terminals which have definitely had leaks is so small that it is not warranted.

The obvious method is to test the assembled lid as a whole, with terminals and fixing studs soldered. This is done quite simply by constructing a jig which will allow high pressure air to be pumped behind the lid so that it can be tested while allowing none to escape round the sides. The jig is merely a base with rubber pads to form a seal and clamps to hold the lid down. A Schrieder valve is screwed into the normal filling hole (via an adaptor) and air is pumped in. To avoid excessive bending of the lid, a rigid strap is fixed across the centre and the whole assembly is placed under water. Those lids showing leaks are rejected.

In practice, each type of lid will require its own jig, though on some closely related types, one jig may be satisfactory for several different lids.

The main can may be tested in a very similar manner to the lid. A plate with rubber pads is clamped to the can. There is a Schrieder valve in this plate through which the air is pumped. The whole is then held under water. It is inadvisable to rely solely on visual inspection for the main can, as several cases of holes in the side of drawn cans have been found, some of which may have normally escaped an inspector's eye.

After the component is assembled and sealed, and immediately prior to it being oil filled, it should be given another air pressure test. The Schrieder valve is again fastened to the filling hole, air is pumped in and the component is held under water. If there are any leaks apparent at this stage, they must have come either from rough handling of the terminals when soldering leads to them, or from distortion of the lid during the final soldering process. It is not anticipated that such faults should occur in any quantity, and careful handling should prevent them.

It is not suggested that the tests recommended are at all complete. There has not been sufficient time to explore all possible avenues fully, and there is no information available as to how tested and approved components stand up to service treatment. It is possible, for example, that small leaks, undetected by the air pressure test, may allow oil to escape by capillary action, and this may not be apparent for months; alternatively, the air pressure test may damage the terminals, and this again may have a delayed reaction. Thus there is still much work to be done on the testing of hermetically sealed components, and many improvements to be made over the existing technique.

5. High Temperature Transformers

When using transformers constructed with normal organic products, it is not possible to work at temperatures above 110 deg. C due to the natural limit of thermal stability of such materials. If, however, the material used has a silicone base or is silicone protected, it is possible to run the component at temperatures of 200 deg. C and over. The advantage of this property is chiefly that the component can be run under conditions which would normally amount to severe over-loading. The possible ratio of size for normal to hot working transformers is considerable; in the case of low voltage power transformers it is anything up to 6 : 1.

5.1. *Properties of Silicones*

The three main types of silicone products—resins, liquids and rubber—have two common basic properties, temperature stability and water resistance. The reason for the first property is the strength of the silicone atom-oxygen atom bond in the molecular chain, requiring much heat energy to break it. Likewise, considering. the molecular structure in relation to the second property, each silicone atom has a hydrocarbon radical bound to it which presents to a surrounding medium a hydrocarbon surface, i.e. similar to oil, which will resist water.

Thus it is seen that a transformer constructed with silica based materials has good properties for hot running under hermetically sealed conditions.[3]

5.2. *Construction of high temperature transformers*

The design of this type of transformer is practically the same as for normal types, except for the core size, number of turns, etc. The materials used though, are nearly all different from conventional types. The winding must be of silicone enamelled wire, interleaved with Silopex paper and impregnated with silicone varnish. When hermetically sealed, the container must be filled with silicone fluid and expansion compensated with Silastic bags or metal bellows.

Apart therefore from the slightly unconventional electrical design needed, the manufacture is quite straightforward. The use of such special materials will naturally increase the cost of the component, but this is compensated for by the reduced size and therefore smaller quantities of material needed.

The dielectric strength of silicone fluid is about the same as that of normal transformer oil, so the limitations on miniaturization due to high voltages have still to be considered.

The viscosity of silicone fluids is more constant than oil, being about the same at normal temperatures and varying from 1 to 1,000 centistokes from 100 deg. C to −40 deg. C compared with 2 to 4,000 centistokes for oil. The specific gravity is about 10 per cent. higher than oil.

The problem of expansion compensation is increased with the higher temperature range and the increased coefficient of expansion of silicone fluid (0·0011 compared to 0·0007 for oil). If the component is sealed at its mid-working temperature, and allowing for normal internal pressures and complete flexibility of bags, an air volume of over 30 per cent. is required. It would seem to be more desirable with these components to employ mechanical devices which need cater for a change of only ±10 in volume. This would, of course, be cheaper.

The size of a component may be decreased even further if the high temperature technique is combined with the use of C type cores or even toroidal types, which show attractive possibilities.[4]

6. Miscellaneous

There are other methods of effecting a seal which have been used. The simplest relies on a pressure join between a metal can and a neoprene top plate, the can edge being rolled over to bite firmly into the neoprene. Leads are brought out through and soldered to eyelets fixed in the same way. This method is very suitable for quite small components having a low temperature range but becomes unsatisfactory at higher temperatures and pressures.

A form of dip has been developed recently which is reputed to be many times superior to the normal dip coats in use and a possible alternative to sealing in a can. It has the advantage of simplicity but the disadvantages are that the temperature rise will be greater than if the transformer was air or oil cooled, and it gives no indication of sealing failure until the component develops electrical faults.

The methods of oil filling transformers in production quantities are too complicated to describe fully. To evacuate the air completely from such inaccessible places as the interior of the winding involves heating the component and the oil and subjecting both to a high vacuum for a period of perhaps several days. It is unnecessary to go to great lengths to remove the microscopic particles of air trapped between turns as its effect is quite negligible except in the case of miniaturized high voltage types.

When medium voltages are to be used a shorter filling cycle may be employed. The recurrent breaking and repumping of the vacuum appears to have the desirable effect of removing air more quickly than if the vacuum were maintained continuously for the same period. It is desirable that the temperature of the oil and the component be about 100 deg. C and that a vacuum better than 0·1 mm mercury be employed. With these conditions it should take about six hours to fill an average component.

The oil used must be carefully checked at frequent intervals to ensure that no great variation takes place in its physical properties. Before oil is used in the vacuum tank it must be thoroughly dehydrated and deaerated. Small quantities of air and water do not appreciably affect the dielectric strength, which is about 7 kV/mm, but if dirt particles are present or if there is sufficient water to produce free globules, then the dielectric strength is considerably reduced.

7. Conclusions

It has been shown that for many reasons hermetic sealing is not easy to achieve. The chief problems, as outlined, are the choice and use of suitable terminals, and the employment of a satisfactory method of expansion compensation which should, wherever possible, avoid the use of breather bags. The main requirements of success are simplicity of design and careful workmanship.

Improved electrical design centred around the use of toroidal or C type cores of high permeability material undoubtedly assists in the miniaturization of sealed components and with good design, the ratio of weight of normal to C type transformers might approach 4 : 1.

8. References

1. W.T.B. Specification No. K114 on Climatic and Durability Testing of Service Telecommunication Equipment. H.M.S.O.
2. Bays, C. F. and Slater, D. "The Hermetic Sealing of Transformers and Chokes Used in Communication Equipment." *Proc.I.E.E.* (Pt. III), Sept. 1947.
3. Bass, S. and Kaupp, T. "Silicons—A New Class of High Polymers of Interest to the Radio Industry." *Proc.I.R.E.*, July, 1945.
4. A. Langley Morris. "Small Power Transformers for Aircraft Electrical Equipment." *Proc.I.E.E.* (Pt. II), June, 1949.

9. Appendix

Properties of Oil

The oil used throughout was of British Standard Specification 148, manufacturers type Silvertown 5D.

The coefficient of expansion of this oil at 15 deg. C is approximately 0·00075 per deg. C. The expansion with a change of temperature however is not linear and it is found that this coefficient increases by 0·0000009 for every degree rise above 15 deg. C and decreases by a similar amount for every degree below 15 deg. C. Thus, at —40 deg. C the coefficient of expansion is approximately 0·00070, and, at 110 deg. C, approximately 0·000835. Small quantities of air or water in solution in the oil should have no effect on the coefficient of expansion.

2. The viscosity increases on cooling and decreases with heating. Thus roughly :—

Temperature	State of Oil	Kinematic Viscosity (Centistokes) (approx)
100°C	Very thin	2
20°C	Normal	20
− 32°C	Very thick, as treacle	1,500
− 40°C	Congealed, as vaseline	4,000

The change of state in itself does not affect the design of the component and may be ignored in general calculations.

3. The thermal conductivity is of the order of 65×10^{-4} watts/deg. C/cm²/cm at ambient temperatures, decreasing with increase of temperature.

4. The maximum permissible working temperature is 120 deg. C.