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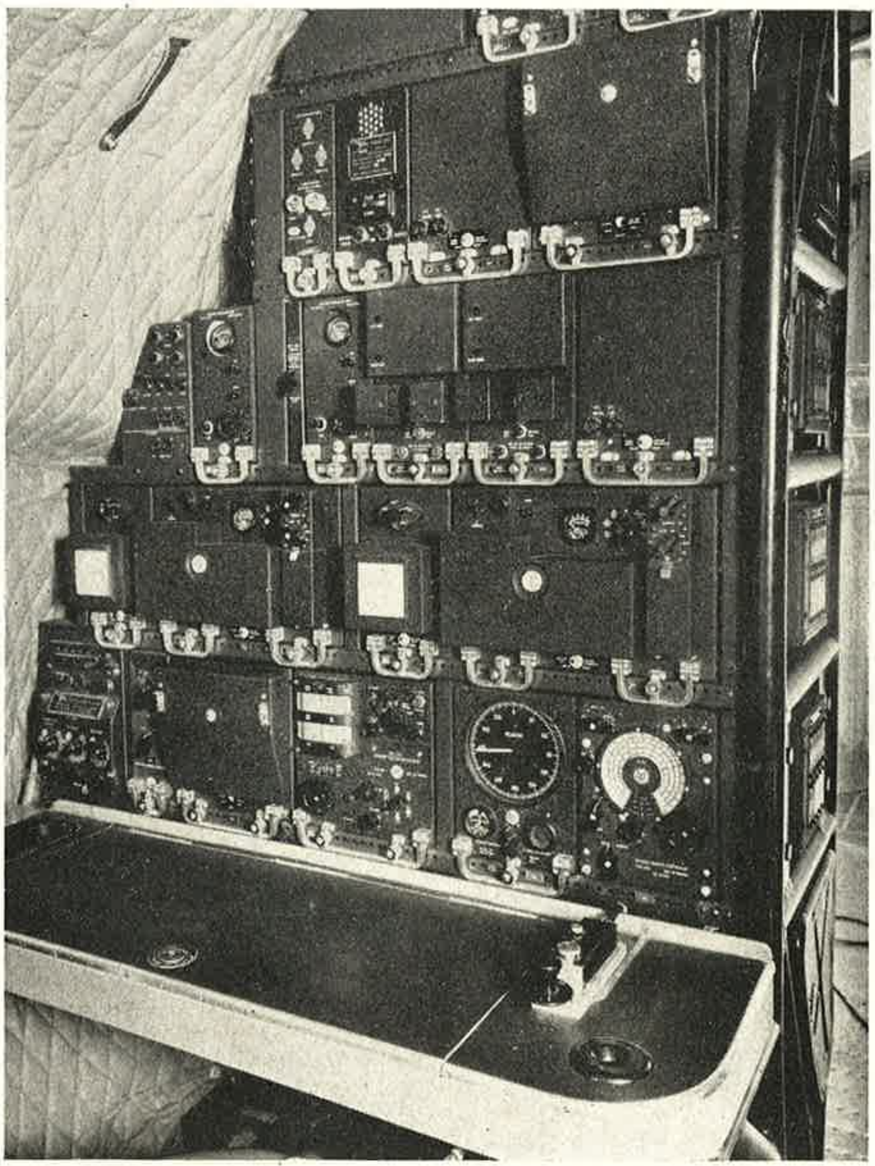
RADIOTRONICS

Volume 18 March 1953 No. 3



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RADIOTRONICS

Volume 18 **March 1953** **Number 3**

By the way —

The cover illustration shows part of the Marconi radio installation of the new "Comet" aircraft. This photograph is reproduced with acknowledgements to Marconi's Wireless Telegraph Company Limited.

Indications are that the second edition of the Radiotron Valve Data Book will be available in about three weeks' time. An announcement will be made as soon as stocks are received; until then orders are not being accepted, as a selling price has not yet been fixed.

An error occurred in the January, 1952, issue, which was devoted to photocells and their applications. The schematic diagram and parts list on page 9 shown as Fig. 3 is actually Fig. 4 and should therefore be interchanged with the diagram and parts list in column 1 of page 10. We would ask all subscribers to amend their copies forthwith to avoid possible confusion later.

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Issues of Radiotronics prior to 1953 are no longer available.

"Proposed Test Procedure for F-M Broadcast Receivers" which appears in this issue was reprinted with permission from Electronic Engineering. We feel this article will be of considerable interest to the industry in view of the increasing use of F-M equipment.

The RCA Application Note dealing with "pencil triodes" is reprinted with acknowledgements to Radio Corporation of America.

Editor:
Ian C. Hansen,
Member I.R.E. (U.S.A.)

CONTENTS

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Proposed Test Procedure for F-M Broadcast Receivers

By D. Maurice,* Ing.E.S.E., A.M.I.E.E., G. F. Newell* and J. G. Spencer*.

In connexion with the high-power tests, using both amplitude modulation and frequency modulation, that are being made with the B.B.C. V.H.F. transmitter at Wrotham, it has been found desirable to decide on a standardized procedure for testing F.M. receivers. Should it be decided that F.M. is to be employed in the future for nation-wide sound broadcasting, it will be important to be able to compare the performance of different receivers. A further reason for attempting to detail methods of test at this early stage is the necessity of discovering the limitations of existing test equipment and the requirements which such equipment as may be developed in the future should fulfil.

The present article describes a procedure that has been found convenient for testing F.M. receivers; it does not attempt to specify what their performance ought to be, but gives, by way of illustration, results obtained on three actual receivers.

The novel instruments required for the tests are described and the test conditions and parameters are detailed. Test procedure is dealt with and as examples the test results on three receivers are given.

The test conditions and parameters and the procedure described were finally decided upon only after careful study of the Interservice Radio and Electronic Measurements Committee document "Interservice Standard Definitions of Radio-Receiver Characteristics", and the Institution of Radio Engineers "Standards on Radio Receivers, Methods of Testing Frequency-Modulation Broadcast Receivers".

Examination of the test equipment and procedures described hereafter will reveal many departures from what may be described as normal medium-wave broadcast receiver measurement practice. While many of these departures are necessitated by V.H.F. F.M. conditions, some are not, and are put forward for consideration now because they seem better adapted for the purpose of performance (as against "designer" type) testing than some methods used hitherto.

The purposes of testing the performance of broadcast receivers include the measurement in objective terms of the subjective assessment which would be given in words by a listener, or the attempt to allocate numbers to the subjective criteria (descriptive words) which the listener would use. Another purpose is to compare receivers between which the subjective performance differences are not very great. Yet another reason lies in considerations of design for which it is desirable to correlate the objective effects of certain methods or circuits adopted by the designer. The tests described hereafter are not intended to include the last reason given, unless this object is achieved fortuitously.

A first example of departure from previous practice is that of the output power noise meter which, it is suggested, should really measure either mean-square voltages or root-mean-square voltages. The reason for this is that it has been found[1] that R.M.S. voltage is a satisfactory parameter of electrical noise of either the random fluctuation or impulsive types in that the annoyance caused by them is closely approximated by their R.M.S. values. An aural weighting network was found to be desirable when measuring noise[1] and the one giving rise to the curve in Fig. 1 was chosen.

A second example is the adoption of 40 per cent. rather than 30 per cent. modulation for standard modulation depth. This is merely because it is thought that 40 per cent. is nearer to average programme modulation depth than is 30 per cent.

It may be asked why, if the aural weighting curve is adopted for noise measurement, it has not been suggested for the measurement of distortion. The reason is simply that the weighing network has been tried and found satisfactory for noise measurement, but so far no experiments have been undertaken with it with regard to distortion, and in the absence of practical evidence it would not be permissible to put it forward.

The choice of 2kc/s as the standard modulation frequency is because this is near the frequency at which the curve in Fig. 1 presents a maximum and thus variations in response due to errors in modulating frequency will be minimized.

The choice of 40db as the standard ratio of signal to unwanted response (noise or interference) is because this ratio corresponds very roughly to a "slightly disturbing" level of undesired response.

The choice of total R.M.S. distortion, unweighted, as being a measure of the subjective effect of non-linearity is admittedly a poor one, but until more work has been published on the subjective effect of distortion it was thought advisable to use a very simple measure.

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* Research Department, B.B.C.

Test Equipment.

STANDARD SIGNAL GENERATOR (S.S.G.).

The procedure described in this report necessitates the availability of two signal generators, each having the following performance features:—

Frequency Coverage.

This shall consist of at least the frequency band or bands which may be allocated to the broadcasting of frequency modulation and also the intermediate frequencies which may be chosen by designers, as well as the image frequencies which would result. A signal generator coverage of 7Mc/s to 133Mc/s is tentatively suggested. This range of frequency will not permit tests at oscillator second harmonic ± intermediate frequency.

Frequency Stability (Short Term).

This must be of sufficiently high order to reduce frequency drift during a measurement to within ± 1kc/s.

Accuracy of Frequency Setting.

The frequency calibration must enable the frequency to be adjusted in not more than 30kc/s steps. A crystal check method should be used to "spot align" the interpolating variable frequency oscillator to an accuracy of not worse than ±0.030 per cent.

Freedom from Hum and Noise Modulation.

The unwanted R.M.S. amplitude modulation of the carrier measured after passage through a C.C.I.F. aural sensitivity network (Fig. 1) should be less than 0.1 per cent. of that due to 100 per cent. sinusoidal amplitude modulation at 2kc/s.

The frequency modulation caused by hum or noise measured after passage through a C.C.I.F. network should produce an R.M.S. output not exceeding that due to sinusoidal deviation of ±5c/s at 2kc/s modulation frequency.

Frequency Modulation.

This must be calibrated in steps of deviation, by a sinusodial modulation, of at most 5kc/s up to a deviation of ±100kc/s and at most 20kc/s steps up to ±300kc/s. The change of mean frequency due to the application of sinusoidal modulation shall not exceed 1kc/s. The unwanted amplitude modulation caused by a sinusoidal deviation of ±75kc/s shall not exceed 1 per cent., for deviations up to ±300kc/s it shall not exceed 5 per cent.

Sinusoidal Amplitude Modulation.

This must be calibrated in steps of at most 10 per cent modulation to a depth of 50 per cent. and this depth of amplitude modulation must not cause a peak frequency deviation in excess of ±100c/s.

Modulation Frequency.

If internal modulation is to be available, then a 2kc/s frequency must be provided and it would be desirable to have 400c/s and 10kc/s as well. Provision for modulation by an external source should exist and be uniform to within ±1db from 30c/s to 15kc/s.

Modulation Distortion (Harmonic).

The total R.M.S. harmonic content of the response due to sinusoidal frequency modulation having any maximum deviation up to ±75kc/s and any frequency between 30c/s and 15kc/s should not exceed 1 per cent. of the R.M.S. modulation. The R.F. bandwidth of the receiver for measuring this must exceed 180kc/s (±90kc/s).

Spurious Outputs.

Any carrier output other than that indicated by the frequency calibration must be at least 60db below the level of the required carrier.

Output Voltage.

The open circuit output voltage shall be variable in steps not greater than 2db from 100mV to 1μV. The internal output impedance shall be not greater than 75Ω substantially resistive. The accuracy of voltage calibration shall be not worse than ±1db ±1μV.

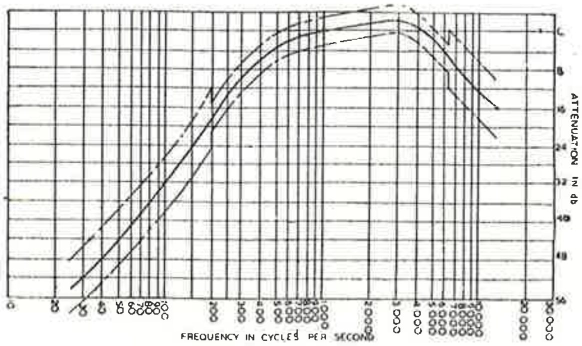


Fig. 1. C.C.I.F. aural weighting curve.

OUTPUT POWER NOISE METER.

This meter must be capable of measuring the power in waveforms of at least 30db crest factor, and must indicate either the R.M.S. or mean square value of the waveform. The meter should be capable of having a frequency response restricted to that of the C.C.I.F. aural network (see Fig. 1). The meter must be capable of giving a full-scale reading for an input power of 5 microwatts. The indicating instrument, which must be critically damped, should have a time-constant of about 0.5 second.

IMPULSE GENERATOR.

In order to investigate the performance of a receiver when receiving impulsive interference it is essential to have a generator of such interference with definite control of the waveform.

The Output Waveform.

This shall consist of discrete pulses of short duration and variable pulse repetition rate covering at least the range from 10c/s to 500c/s. If the P.R.F. (pulse repetition frequency) is adjustable by switching to fixed repetition rates one rate shall be 500c/s.

The pulse shape is relatively unimportant provided the pulses are unidirectional and the pulse duration sufficiently short to produce a frequency spectrum consisting of uniformly spaced spectral lines having amplitudes uniform to within ±1db over the frequency range from 100kc/s to 133Mc/s.

Output Voltage.

With a P.R.F. of 50c/s this shall be not less than 17.5 R.M.S. μV per square root "integral bandwith" measured in kc/s and chosen anywhere within the range of 100kc/s to 133 Mc/s.

The value of 17.5μV R.M.S. corresponds approximately to 100 peak μV per kc/s of "integral bandwidth" for a pair of bandpass coupled circuits having a coupling parameter $KQ = \sqrt{2}$.

The frequency limits defining "integral bandwidth" shall be those frequencies at which the steady state response has fallen by 20db from the nominal mid-frequency steady state response. In a numerical example, if the "integral bandwidth" of a receiver R.F. circuit is Bkc/s the impulses will produce 17.5 $\sqrt{B}$ R.M.S. μV or approximately 100 B peak μV.

The Output Attenuation.

This shall be in steps of not greater than 2db to 60db below maximum output with a further 20db obtainable by a switch controlling the waveform amplitude before the variable attenuator.

The Output Impedance.

This shall be not greater than 75 ohms and shall be substantially resistive.

Test Standards.

STANDARD INPUT IMPEDANCE.

The tests should all be carried out with the S.S.G. matched to the nominal input impedance of the receiver. This should be taken as 75 ohms unless otherwise stated.

STANDARD LOAD RESISTANCE.

The output test load should be a resistance of value equal to the D.C. resistance of the loudspeaker speech coil. While it is admitted that this definition does not accord with actual conditions at all audio frequencies, it is none the less a convenient means of comparison between receivers and is very easily determinable.

STANDARD OUTPUT POWER.

This shall be measured in the standard output resistance and shall be 50mW for all types of receivers unless otherwise stated.

STANDARD MODULATION FREQUENCY.

This shall be 2kc/s. The reason for this choice is that the C.C.I.F. aural weighting curve (see Fig. 1) presents a maximum at this frequency. In addition, the shape of this curve is such that errors in frequency around 2kc/s give rise to smaller errors in response than at any other convenient frequency.

STANDARD MODULATION DEPTH.

This shall be 40 per cent. of the maximum nominal depth permitted by the system of modulation in use. In the case of F.M. with pre- and de-emphasis it may be desirable to increase the modulation depth by an amount which will account for the necessary pre-emphasis at 2kc/s. For example, a 50μsec pre-emphasis requires that the modulation depth be increased from 40 per cent. to 47.5 per cent at 2kc/s modulation frequency.

STANDARD RATIO OF SIGNAL TO UNWANTED RESPONSE.

This shall be taken as a C.C.I.F. weighted 40db ratio between A.F. signal and unwanted response, both being measured with the standard output noise power meter. For this test, standard modulation frequency and depth shall be used, and the A.F. gain control adjusted to obtain standard output.

Test Procedures.

Many of the following tests may require to be repeated near the edges of the radio frequency coverage as well as in the centre.

SENSITIVITY.

The sensitivity of an F.M. receiver can be expressed as the smallest input signal required to satisfy all the following three conditions:—

(a) a satisfactory listening level [standard output]
(b) satisfactory programme quality [10 per cent. distortion for 100 per cent. modulation]
(c) a satisfactory low hum and background noise level [–40db].

Absolute Sensitivity.

This is the S.S.G. "open circuit voltage" required to produce standard output power. Standard modulation frequency should be used, and at standard modulation depth. The receiver gain controls should be at maximum gain for this test.

Maximum Deviation Sensitivity for 10 per cent. Harmonic Distortion.

This is the S.S.G. "open circuit voltage" which, modulated to a depth of 100 per cent. at a frequency of 400c/s, unless otherwise specified, gives rise to an audio output distortion of 10 per cent. The bandwidth of the measuring device shall not restrict that of the receiver. This percentage distortion shall be the product of 100 and the ratio: R.M.S. distortion/R.M.S. (fundamental + distortion). The receiver A.F. gain control should be so adjusted that the total output is equal to the standard output. If the distortion is less than 10 per cent. at the absolute sensitivity input, then the percentage distortion at this input should be measured.

Sensitivity for Standard Ratio of Signal-to-Noise.

This is the S.S.G. "open circuit voltage" required to produce the standard ratio of signal-to-noise.

Signal-to-Hum Ratio.

This is the deviation as a percentage of the system's maximum, necessary to produce the standard ratio of signal-to-hum. The carrier input should be 10 millivolts and the standard modulation frequency should be used.

FIDELITY.

These tests are intended to measure the performance of the receiver in reproducing the received intelligence or modulation without distortion.

Harmonic Distortion, Variation with Modulation Depth.

By suitable adjustment of the receiver A.F. gain control standard output power shall be obtained with standard modulation depth and at a frequency of 400c/s. The R.F. input carrier shall be 10mV. A graph of percentage R.M.S. harmonic distortion against percentage modulation shall be drawn for modulation percentages varying from 0 to 100. The bandwidth of the harmonic measuring device shall not restrict that of the receiver. It may be desirable to repeat this test with a 1mV input.

Maximum Output Power for 10 per cent. Harmonic Distortion.

With an R.F. input carrier of 10mV modulated to a depth of 100 per cent. at 400 c/s, adjust the A.F. gain control to obtain the maximum output power giving rise to 10 per cent. distortion.

Modulation Frequency Characteristic.

This is a curve of audio amplitude plotted against modulation frequency at constant modulation depth when the former is varied from 30c/s to 12kc/s. The carrier input shall be 10mV and the audio gain adjusted to produce standard output power with standard modulation depth and frequency. It should be remembered that a uniform curve will not be obtained if the receiver employs de-emphasis.

Audio Frequency Input-Output Characteristic.

This test is applicable when the receiver is provided with gramophone pick-up terminals.

With A.F. gain control at maximum plot the curve showing output voltage across the standard load resistance against A.F. input voltage at a frequency of 2kc/s.

SELECTIVITY.

The purpose of these tests is to ascertain the capability of the receiver to reject all transmitted signals other than the one to which it is tuned.

Adjacent Channel Suppression Ratio.

For this test the receiver shall be adjusted to produce standard output power when tuned to a carrier of 1mV with standard modulation frequency and depth. This modulation shall then be switched off and a second carrier (with standard modulation frequency and depth) tuned to one of the adjacent channel frequencies (±200kc/s from required channel unless otherwise stated). The amplitude of the adjacent channel carrier shall be adjusted until the audio output of the receiver is 40db below standard output power, that is, until standard ratio of signal to unwanted response is obtained. The ratio of the adjacent carrier amplitude to required carrier amplitude (1mV) is noted. This test is repeated for both adjacent channels.

Second and Third Channel Suppression Ratios.

These are measured as above, but with the frequency separations of ±400kc/s for second channel and ±600kc/s for third channel.

Image Channel Ratio.

This is measured as described above with the exception that the second carrier (interfering carrier) is separated from the required carrier by twice the intermediate frequency.

Intermediate Frequency Suppression Ratio.

The procedure described above is repeated with the frequency of the interfering carrier adjusted to the intermediate frequency of the receiver.

Spurious Frequencies Suppression Ratios.

The procedure described above is repeated with the frequency of the interfering carrier adjusted to any frequency liable to give rise to spurious response. Such frequencies include integral multiples of the intermediate frequency, and various combinations of receiver superheterodyne local oscillator harmonics and the intermediate frequency and multiples of it.

FREQUENCY STABILITY.

These measurements are required as a guide to the manual tuning necessary to keep the receiver tuned to a wanted carrier. They are based on the assumption that circuits operating at intermediate frequency will not materially affect the issue.

Oscillator Drift.

This test is to ascertain how much the local oscillator frequency changes with temperature increase from first switching on the receiver. The receiver should be switched on and tuned to a stable frequency carrier of 1mV strength. The local oscillator frequency should be measured and changes of this frequency plotted against time until the rate of frequency change with time becomes negligible. Steps should be taken to maintain stable mains voltage.

Dependence of Oscillator Frequency upon Mains Voltage.

This test is to ascertain within what limits of mains voltage variation the receiver may conveniently be used. The receiver should be switched on and a sufficient lapse of time allowed for the frequency drift with temperature rise to have become negligible. Tune receiver to a stable frequency carrier of 1mV strength. The mains supply voltage is then varied in 5 or 10 volt steps over such a voltage range as will cause the receiver local oscillator to change appreciably.

From a graph of frequency against mains voltage it is then possible to state within what limits of voltage variation the receiver must be operated.

CO-CHANNEL SUPPRESSION RATIO.

This is to test the receiver performance when receiving a wanted carrier and an unwanted (distant station) carrier on the same frequency.

The receiver should be tuned to a carrier of 1mV with standard modulation frequency and depth. The audio gain control shall be adjusted to produce the standard output power as measured with the standard output power noise meter. The modulation shall then be switched off.

A second carrier having standard modulation frequency and depth shall then be connected to the receiver input in parallel with the first (unmodulated carrier) and tuned to within 1kc/s of the same frequency. The amplitude of this modulated carrier shall be adjusted until the standard ratio of signal to unwanted response is obtained. The ratio of this carrier amplitude to 1mV is the required suppression ratio. It may be necessary to re-adjust the receiver tuning for minimum interference in the presence of both carriers.

AMPLITUDE MODULATION SUPPRESSION.

The purpose of this test is to measure the efficiency of the amplitude limiting circuits of the receiver.

The receiver should be tuned to a carrier of 1mV frequency modulated to the standard depth and at standard frequency. The audio gain should be adjusted to produce standard output power. A band-pass filter attenuating frequencies outside the band 250c/s to 8kc/s should be interposed between the receiver audio output and the standard output power noise meter with the C.C.I.F. network in circuit. The frequency of the modulation should then be changed to 10kc/s so that the audio output at this frequency will not be read on the standard output power noise meter. The carrier should then be simultaneously amplitude modulated to standard depth and at standard frequency. The meter will then read the unwanted output due to amplitude modulation while not reading the output due to frequency modulation. The ratio of the standard output power due to frequency modulation to the output power due to amplitude modulation should be recorded.

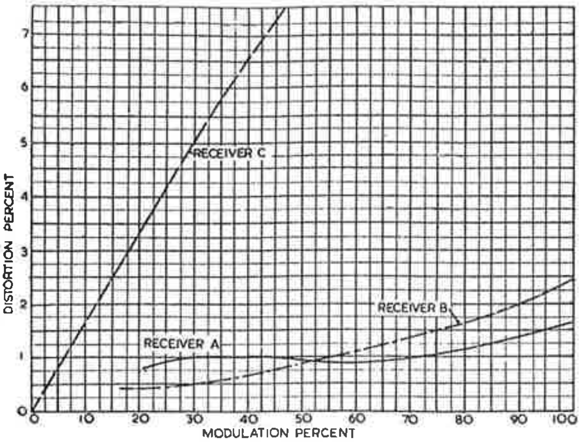


Fig. 2. Variation of harmonic distortion with modulation depth.

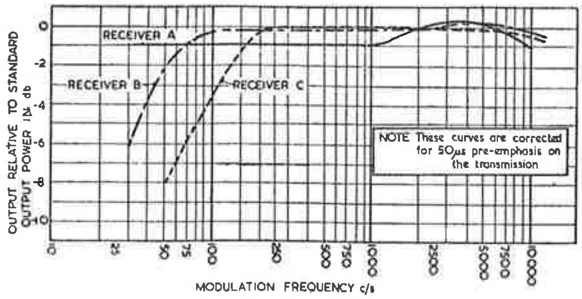


Fig. 3. Modulation frequency characteristic.

This measurement may be repeated with the wanted carrier increased to 10mV.

IMPULSIVE INTERFERENCE PERFORMANCE.

This test is intended to show the performance of the receiver when receiving a carrier and impulsive interference. The resulting curve should show this performance for conditions including the improvement threshold of the frequency modulation receiver for impulsive interference.

The receiver should be tuned to a carrier of 0.5mV having standard modulation depth and frequency and adjusted to produce the standard output power. A band-pass filter attenuating frequencies outside the band 250c/s to 8kc/s shall be interposed between the receiver audio output and the standard output power noise meter. The modulation frequency shall be changed to 10kc/s.

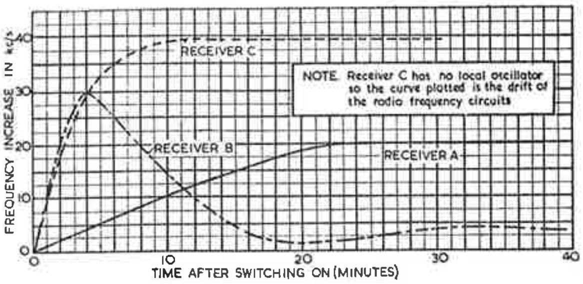


Fig. 4. Oscillator drift.

A source of impulsive interference shall then be connected to the receiver input in parallel with the source of frequency modulated carrier.

The impulsive interference repetition frequency shall be adjusted to 500c/s unless othewise stated. A curve is then plotted of C.C.I.F. weighted output power (in the pass band obtained with the band-pass filter) against impulse amplitude in peak μV/kc/s. The impulse amplitude shall be varied from the maximum obtainable down to such a value that further reduction does not affect the receiver output noise level. This test should be repeated with the frequency modulation of the signal generator switched off.

Performance Tests on Three Receivers.

Three different types of frequency modulation receivers were tested at a frequency of 90Mc/s according to the procedure described above, and the results are reproduced here as typical examples:—

Receiver A. This is a high grade frequency modulation receiver using thirteen valves plus a rectifier.

Receiver B. This is a receiver designed for simplicity compatible with a reasonable performance and uses six valves plus a rectifier.

Receiver C. This is a super-regenerative two valve adaptor intended to supply an audio output to the pick-up terminals of a normal broadcast receiver.

SENSITIVITY.

Absolute Sensitivity.

Receiver A	52μV.
Receiver B	60μV.
Receiver C	Not applicable.

Maximum Deviation Sensitivity for 10 per cent. Harmonic Distortion.

Receiver A	less than 52μV.
Receiver B	60μV.
Receiver C	With an input of 10mV the distortion is 14 per cent. and is greater for all other inputs.

Sensitivity for Standard Ratio of Signal-to-Noise.

Receiver A	28μV.
Receiver B	25μV.
Receiver C	1.0mV.

Signal-to-Hum Ratio.

Receiver A	2.0 per cent.
Receiver B	2.0 per cent.
Receiver C	41.0 per cent.

FIDELITY.

Harmonic Distortion, Variation with Modulation Depth.

See Fig. 2.

Maximum Output for 10 per cent. Harmonic Distortion.

Receiver A	Maximum output power was 3 watts at which the distortion was 3.0 per cent.
Receiver B	2.1 watts.
Receiver C	Not applicable but distortion was greater than 10 per cent. at all output levels.

Modulation Frequency Characteristic.

See Fig. 3.

SELECTIVITY.

Adjacent Channel Suppression Ratio.

	—200 kc/s.	+200 kc/s.
Receiver A	9.0db	– 6.0db
Receiver B	11.0db	– 1.0db
Receiver C	–35.0db	–24.0db

Second and Third Channel Suppression Ratios.

	—600 kc/s.	—400 kc/s.	+400 kc/s.	+600 kc/s.
Receiver A	>34 db	>34 db	30 db	>34 db
Receiver B	>34 db	31 db	29 db	>34 db
Receiver C	– 1.8db	– 4.1db	– 9.1db	– 6.0db

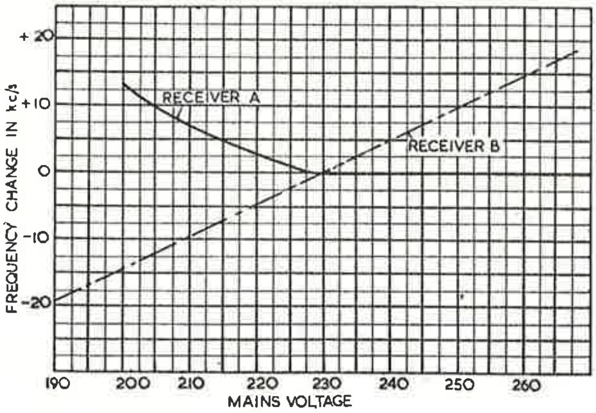


Fig. 5. Dependence of oscillator frequency on mains voltage.

Image Channel Ratio.

Receiver A	21.8db.
Receiver B	12.7db.
Receiver C	Not applicable.

Intermediate Frequency Suppression Ratio.

Receiver A	32db
Receiver B	>34db
Receiver C	Not applicable

Spurious Frequencies Suppression Ratios

Receiver A	31.6Mc/s	21db
Receiver B	100Mc/s	14db
Receiver C	None	

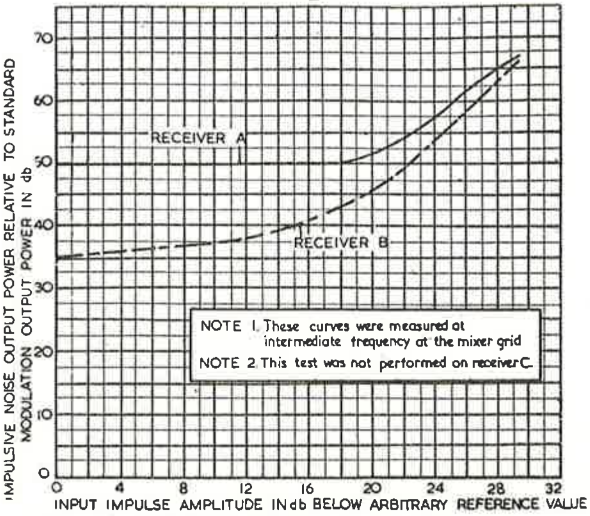
FREQUENCY STABILITY

Oscillator Drift

See Fig. 4

Dependence of Oscillator on Mains Voltage

See Fig. 5.



NOTE 1. These curves were measured at intermediate frequency at the mixer grid

NOTE 2. This test was not performed on receiver C.

Fig. 6. Impulsive interference performance.

CO-CHANNEL SUPPRESSION RATIO

Receiver A	– 6db
Receiver B	–12.5db
Receiver C	–35db

AMPLITUDE MODULATION SUPPRESSION RATIO

Receiver A	38db
Receiver B	27db
Receiver C	11db

IMPULSIVE INTERFERENCE PERFORMANCE

See Fig. 6

Conclusions.

From the tests on the three example receivers one may say that as regards sensitivity Receiver A is suitable for the reception of signals greater than 52μV while B requires 60μV or more. Receiver C is inferior to the other two for all values of signal strength. As far as fidelity and selectivity are concerned it can be seen that Receivers A and B are comparable, whereas Receiver C is much inferior. As regards susceptibility to impulsive interference, Receiver A is definitely superior to B, but it was not possible to test Receiver C because of the lack of a suitable impulse generator.

Acknowledgment.

The authors are grateful to the Chief Engineer of the British Broadcasting Corporation for his kind permission to publish this work.

REFERENCE

Maurice, Newell and Spencer: Electrical Noise: *Wireless Eng., Jan.,* 1950.

RCA Application Note **AN-156**

ELECTRODE-TERMINAL CONNECTIONS FOR PENCIL-TYPE UHF TRIODES

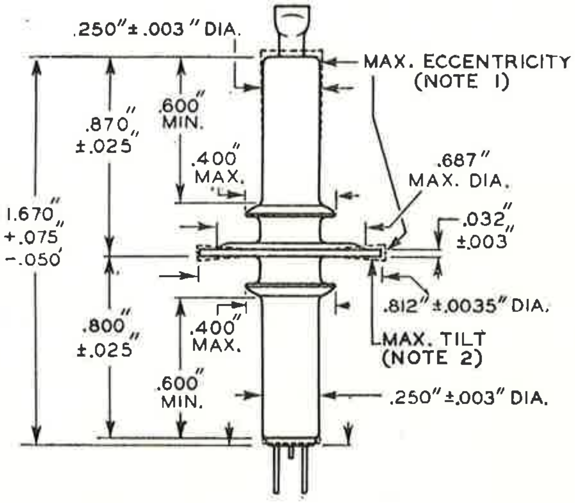
Pencil-type uhf triodes are designed primarily for use as amplifiers at frequencies up to at least 1000 megacycles or as low-power oscillators at frequencies up to at least 3000 megacycles. They are suitable for use in coaxial-line, parallel-line, or lumped circuits. This Note discusses the mechanical and thermal problems involved in the use of these tubes, and describes several types of electrode-terminal connections suitable for use with them.

A number of considerations should be taken into account in the selection of electrode-terminal connections for use with pencil-type uhf triodes. The connectors, for example, must furnish adequate electrical contact without introducing undue mechanical strain. The connectors must also have low inductance. In addition, the anode connector should provide sufficient heat conduction to maintain the temperature of the glass-to-metal anode seal below 175 degrees Centigrade at all times.

Mechanical considerations.

The glass-to-metal seals used in pencil-type triodes are very strong in compression, but less strong under conditions of tension, torque, or bending. Connections to the electrode terminals, therefore, should be such that they place a minimum of tension, torque, or bending stress on the tube. Sufficient allowance should be made in the connectors for a small amount of terminal eccentricity or grid-flange tilt in the tubes. Precautions should be taken to prevent any distortion of the grid flange by the grid connector, because twisting or bending this flange will crack the glass-to-metal seals. In general, one of the three electrode terminals of the tube — the cathode cylinder, the grid flange, or the anode cylinder — should be fastened fairly rigidly. Connectors to the other two terminals should have sufficient spring to allow for dimensional variations within the range of manufacturing tolerances. An outline drawing of a pencil-type triode is shown on page 8; the maximum variations encountered under present specifications are indicated by dotted lines.

DIMENSIONAL OUTLINE



NOTE 1: MAX. ECCENTRICITY OF ℄ (AXIS) OF ANODE TERMINAL OR GRID-TERMINAL FLANGE WITH RESPECT TO THE ℄ (AXIS) OF THE CATHODE TERMINAL IS 0.008".

NOTE 2: TILT OF GRID-TERMINAL FLANGE WITH RESPECT TO ROTATIONAL AXIS OF CATHODE TERMINAL IS DETERMINED BY CHUCKING THE CATHODE TERMINAL, ROTATING THE TUBE, AND GAUGING THE TOTAL TRAVEL DISTANCE OF THE GRID-TERMINAL FLANGE PARALLEL TO THE AXIS AT A POINT APPROXIMATELY 0.020" INWARD FROM ITS EDGE FOR ONE COMPLETE ROTATION. THE TOTAL TRAVEL DISTANCE WILL NOT EXCEED 0.020".

At lower power inputs and frequencies, where circuit inductances and thermal conductivity are not major considerations, fuse clips may be used for anode and cathode connections, and various types of spring clips for grid connections. Typical connectors suitable for applications in which power inputs and frequencies are relatively low are shown in Fig. 1. For somewhat higher power inputs or frequencies, the anode connector shown in Fig. 2a and the grid connectors of Fig. 2b provide appreciably lower inductance and better heat conductivity than those of Fig. 1.

In re-entrant-type oscillator circuits*, the grid flange acts as a support for the cylindrical grid connector. The connector, therefore, must exert a clamping action on the grid flange. Fig. 3 shows a grid connector for a re-entrant oscillator operating at 3375 megacycles. Clamping action is provided by

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* Klystrons and Microwave Triodes, D. R. Hamilton and J. K. Knipp, M.I.T. Radiation Laboratory Series, Vol. 7, Sec. 7.2 page 173.

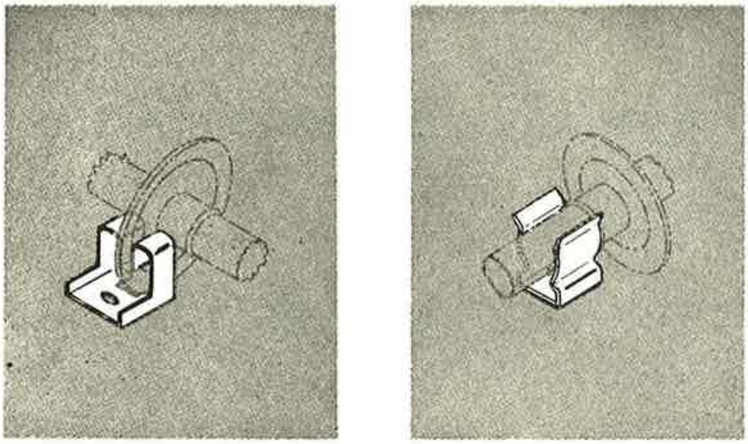

Fig. 1 - Electrode-Terminal Connectors for Use at Relatively Low Power Inputs and Frequencies.

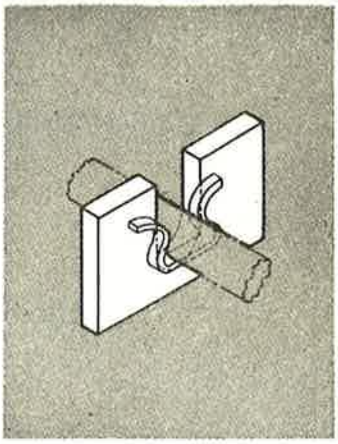

Fig. 2a - Anode Connector for Use at Higher Power Inputs and Frequencies.

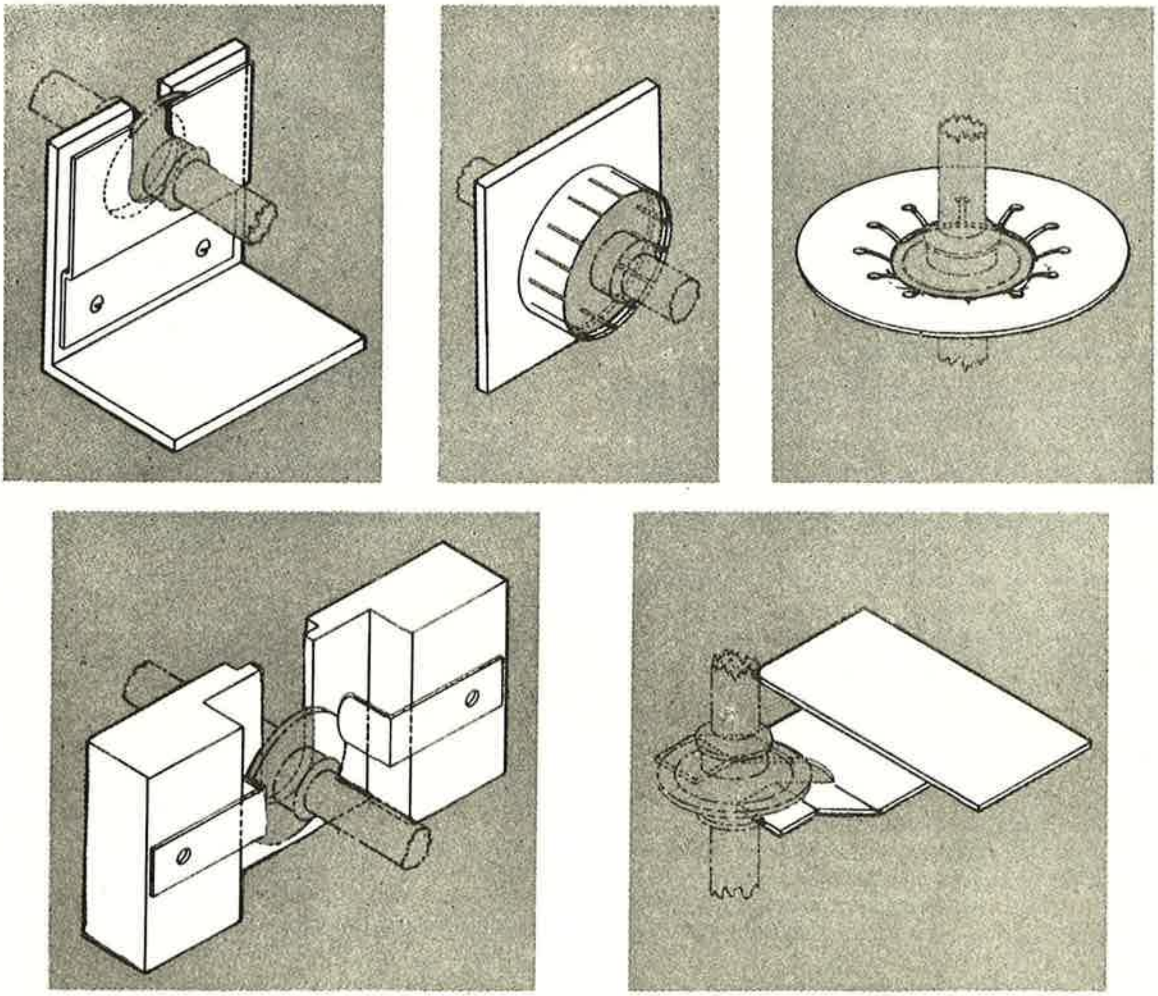

Fig. 2b - Typical Grid Connectors having Lower Inductance and Better Heat Conductivity than the Spring Clip shown in Fig. 1.

means of a bevelled groove which forms a seat for the grid flange. The shape of this groove is such that the cathode side of the grid flange always rests on the slope of the groove. As a result, the bevelled groove presses against the grid flange to seat it on the shoulder of the grid connector. The angle of the bevel is determined by the type of material used in the connector, the thickness of the material, and the amount of clamping action desired. For the $\frac{1}{16}$-inch thick brass connector shown in Fig. 4, a suitable angle of the bevel is 15 degrees. For applications where the oscillator may be subjected to vibrations, it may be advisable to increase the angle.

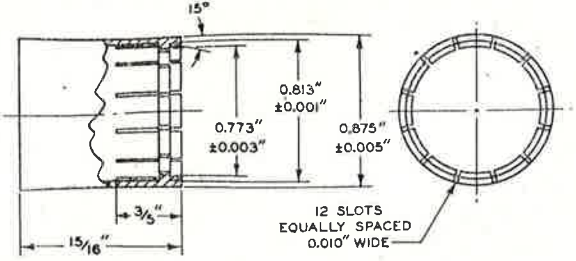

Fig. 3—Cylindrical Grid Connector for use in re-entrant Oscillator Circuits.

A large angle of bevel, however, tends to produce a clamping action so tight that it is difficult to remove the connector from the grid flange without the use of special tools.

The heater leads of all pencil triodes in current production fit sockets such as Cinch No. 54A16325. Heater leads should not be soldered directly to circuit elements, because the heat of soldering may crack the glass seals around the heater leads and damage the tube.

Thermal considerations.

When the anode dissipation of a pencil-type triode exceeds 2.5 watts, special measures are necessary to cool the anode and thus to keep the temperature of the anode seal below 175 degrees Centigrade.

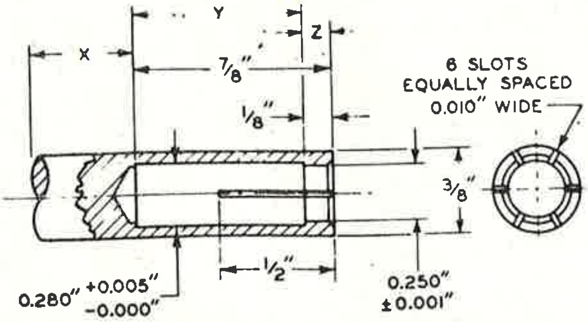

Fig. 4—Anode Connector for Use in Concentric-Line Circuits.

Cooling can be accomplished by the use of a connector which makes a firm and large-area contact with the anode and, therefore, conducts as much heat as possible to elements of the external circuit. Heat conducted to the external circuit can then be removed by radiation or by convection. The heat-conducting path may conveniently be a part of the electrical circuit, such as the centre conductor of a coaxial line.

Fig. 4 illustrates a satisfactory type of anode contact for use in concentric-line circuits. Such a contact provides both good electrical connection and good cooling. The cathode connector for a concentric-line circuit may be of the same form, except that it should be hollow throughout its entire length to accommodate the heater leads and socket. Where lumped-circuit techniques are used, radiator cooling may be employed for the anode cylinder. A diagram of a suitable radiator is shown in Fig. 5.

In addition to having good thermal conductivity, the material used for the anode connector should be non-magnetic and have good spring properties so that the connector can provide a good electrical connection without introducing excessive mechanical strain. Some of the materials which may be used for such connectors are hard brass, phosphor bronze, beryllium copper, and special resistance-welding alloys such as Mallory 100†. Actual choice of the proper material may be governed by considerations of cost, durability, heat conductivity, and availability. Electrical conductivity may be only a secondary consideration if the material is to be silver plated.

Material	Relative Conductivity in per cent.‡	Thermal Conductivity§
Mallory 100	50	2.93
Brass		
85 Copper, 15 Zinc	37.2	1.58
66 Copper, 34 Zinc	26	1.2
Beryllium Copper		
2 Beryllium, 98 Copper ..	20.8	0.94
Phosphor Bronze		
4 Tin, 0.5 Phosphor,		
Balance Copper	18.2	0.81

‡ Pure copper = 100 per cent.

§ Watts per unit area per degree Centigrade times unit length.

Table I

Table I lists the relative electrical conductivity and the thermal conductivity of the materials suggested for use in anode connectors. Beryllium copper and phosphor bronze, which are generally used for conventional spring connectors, have rather low thermal conductivity. Brass has reasonably high thermal conductivity, but spring fingers made from it tend to weaken and break after repeated flexing. Mallory 100 alloy has superior thermal conductivity to brass and about the same spring properties as brass, but withstands repeated flexing at high temperatures somewhat better.

Temperature measurements.

Because maintenance of the maximum anode-seal temperature below 175 degrees Centigrade is of the utmost importance, the ultimate test of the cooling capabilities of any anode connector is an actual measurement of the temperature of the seal. Either of the following two methods may be used for this measurement:

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† P. R. Mallory and Co., Inc., Indianapolis, Indiana.

(1) with the tube under normal anode-dissipation conditions, but without radio-frequency voltages present, measure the temperature of the anode seal by means of a thermocouple;

(2) with the tube under actual operating conditions, use temperature-sensitive paint or crayon• to determine the anode-seal temperature.

The second method is usually more convenient because of the difficulty of determining accurately the anode dissipation of the tube under actual operating conditions.

The heat-dissipation capabilities of an anode connector are determined by such factors as the area of contact, the effective length of the conducting path, the thermal conductivity of the metal used, and the ambient temperature of operation. A method of calculating the heat-dissipation capabilities of a connector is given in Appendix 1.

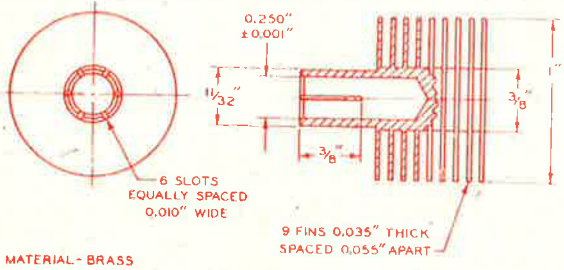

Fig. 5—Radiator Suitable for Cooling the Anode in Lumped Circuits.

When a radiator is used for anode cooling, the amount of heat dissipated by the radiator is a function not only of the factors mentioned above, but also of the air circulating past the cooling fins. If no blower is used, the amount of air circulating past the cooling fins. If no blower is used, the amount of air circulating past the fins may be limited by the proximity of other circuit components or shields. In a typical circuit arrangement, a pencil triode using the radiator shown in Fig. 5 and no blower, was operated at an ambient temperature of 90 degrees Fahrenheit (32.2 degrees Centigrade), with a solid shield 6 inches long and 6½ inches wide on opposite sides of the radiator at a distance of 2½ inches from it, and no shield on the other two sides of the radiator or above it. The radiator, shielded in this manner, maintained the seal temperature below 175 degrees Centigrade when the anode dissipation of the tube was 5.5 watts. The allowable dissipation obviously would be much higher if a blower were used.

Appendix 1

The heat-dissipation capabilities of an anode connector can be estimated quite accurately through the use of the relation

$$\Delta t = \frac{WL}{KA}$$

where Δt = temperature drop across the connector in degrees Centigrade (difference between anode-seal temperature and temperature at end of connector).

W = anode dissipation of tube in watts.

L = length of connector in centimeters.

K = thermal conductivity of material used in connector in watts per unit area (in square centimeters) per degree Centigrade times unit length (in centimeters).

A = cross-sectional area of connector in square centimeters.

If the cross-sectional area and the thermal conductivity of the connector are not uniform throughout the entire length, the temperature drop should be computed separately for each uniform section, and the values added to obtain the total temperature drop. In the connector shown in Fig. 4, for example, if Mallory 100 alloy is used throughout, then the thermal conductivity, as given in Table I, is 2.93 watts per centimeter per degree Centigrade. There are differences, however, in cross-sectional area. The area in square centimeters of X, the solid portion of the connector, is

$$A_X = \pi\left(\frac{d^2}{2}\right)$$

When the ⅜-inch diameter is converted to centimeters, therefore,

$$A_X = 3.14\left(\frac{0.375 \times 2.54^2}{2}\right) = 0.712\ \text{cm}^2$$

To find the area of the "fingers" of the connector, it is necessary to subtract the area of the hollow portion from the area of the solid cylinder. The area of the slots may be neglected. Thus, the area in square centimeters of portions Y and Z of the connector, respectively, are

$$A_Y = 0.712 - 3.14\left(\frac{0.280 \times 2.54^2}{2}\right) = 0.315\ \text{cm}^2$$

$$A_Z = 0.712 - 3.14\left(\frac{0.250 \times 2.54^2}{2}\right) = 0.396\ \text{cm}^2$$

Then, if the anode dissipation of the tube is 6.5 watts, and if the section X is 4 inches long, the temperature drop across section X is

$$\Delta t_X = \frac{6.5 \times 2.54 \times 4}{2.93 \times 0.712} = 31.7^\circ\text{C}$$

The drop across sections Y and Z respectively, is

$$\Delta t_Y = \frac{6.5 \times 0.750 \times 2.54}{2.93 \times 0.315} = 13.42^\circ\text{C}$$

$$\Delta t_Z = \frac{6.5 \times 0.125 \times 2.54}{2.93 \times 0.396} = 1.78^\circ\text{C}$$

The total temperature drop across the connector is 31.7 + 13.42 + 1.78, or 46.9 degrees Centigrade. Thus, if the temperature at the end of the connector is 30 degrees Centigrade the temperature of the anode seal is 30 + 46.9, or 76.9 degrees Centigrade.

The relation given above may also be used to estimate the maximum power which can be conducted through a given connector without exceeding the maximum anode-seal temperature of 175 degrees Centigrade or to estimate the length required to obtain a given drop in temperature.

• Such as Tempilaq or Tempil Stik, made by the Tempil Corporation, 132 W. 22nd St., New York 11, N.Y.