TRANSMISSION MEASURING SET TM/1

Description

Function—The transmission measuring set **TM/1** is used in conjunction with the variable frequency tone source **TS/4,** oscillator amplifier **OA/1,** variable attenuator **AT/2** and amplifier detector **AD/2.**

It provides, among others, facilities for,

(*a*) Sending tone at any of five absolute levels, with reference to a zero of 1 milliwatt in a 600 ohm resistance, e.g. for the calibration of programme meters and amplifier detectors and for making level measurements in the A.C. testing of lines.

(*b*) Making 600 ohm test gain measurements on L.F. amplifiers and for determining their 600 ohm test frequency response characteristics.

(*c*) Making 600 ohm test loss measurements on equalisers, filters and other networks, and for determining their 600 ohm test frequency loss characteristics.

Circuit—The transmission measuring set (See Fig. 1) is made up of two distinct circuits, namely, a **sender circuit** comprising that part of the circuit included between the **Sender-Input** and **Sender-Output** jacks, and a **gain measuring circuit** comprising that part of the circuit included between the **Gain-Input** and **Gain-Output** jacks.

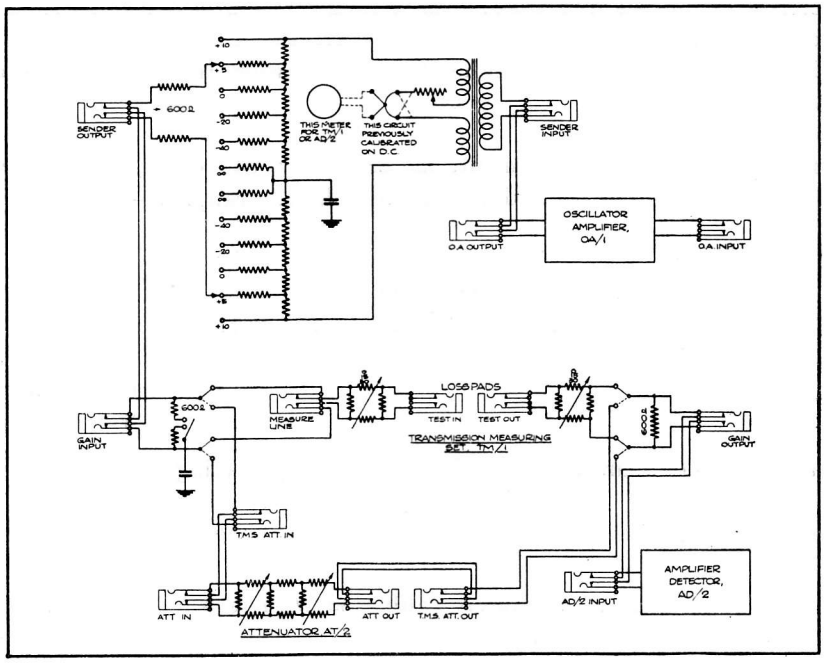

Fig. 1. General Schematic

Description (*Contd*)

The sender circuit works in conjunction with the tone source and enables the output to be adjusted to certain definite levels with reference to a zero power of 1 milliwatt in a 600 ohm resistance. For this purpose, a sending network is provided consisting of a low-resistance potentiometer (122 ohms) tapped at suitable points and including resistances which build out the sending impedance at all levels to 600 ohms. Provision is made for sending at levels of +10, +5, zero, −20, −40 and $-\infty$ decibels.

A thermocouple circuit is provided for adjusting the value of the current and provision is made for calibrating the thermocouple on direct current.

The centre point of the 122 ohm resistance is earthed through a 1μF. condenser. It is, therefore, important when the circuit under test is unbalanced, e.g. earthy on one side, for the connection to the sending circuit to be made via a **repeating coil,** because otherwise the results obtained with the testing equipment may be seriously inaccurate.

The gain measuring circuit consists of two branches with change-over switching enabling either to be connected between the **Gain Input** and **Gain Output** terminals. One branch includes **Test In** and **Test Out** jacks, between which the apparatus to be tested is connected, and **loss pads** on either side of the test jacks controlled by key switches. Provided that the circuit under test has input and output impedances of 600 ohms, the loss pads together introduce losses of zero, 30 db. or 60 db., according to their key setting. The other branch of the circuit includes the variable attenuator **AT/2.**

The meter is calibrated (red scale) over a range of ±2 db., the divisions indicating approximately 0.2 db. The reading denotes the correction to be applied to the attenuator reading, and should be added to the attenuator reading when the deflection is positive, and subtracted when it is negative.

Range and Accuracy—The equipment, as ordinarily connected, enables readings to be obtained to an accuracy of ±0.2 db. over the following ranges :—

Loss measurements	.. ..	0 to 62 db.
Gain do.	.. ..	0 to 60 db.
Level do.	.. ..	+10 to −55 db. (with respect to a zero level of 1 milliwatt in a 600 ohm circuit).

These ranges can, of course, be extended if desired by making suitable connections.

Meter and Controls—The meter provided on the panel serves three purposes, as follows :—

(*a*) D.C. milliammeter accurately calibrated with its shunt to read 40 mA. at its mid-scale deflection.

(*b*) Galvanometer for indicating the output of the thermocouple.

Description (*Contd*)

(*c*) Level indicator for indicating in the output of the amplifier detector, used primarily as a galvanometer but having a decibel scale (marked in red) covering a range of ±2 db. with divisions of 0.2 db.

The controls provided on this panel are as follows :—

Two—3-position keys controlling the galvanometer and thermocouple switching.

One—3-position double key designated −60 db., 0 and −30 db., controlling the attenuation introduced by the **Loss Pads** in the test branch of the circuit.

One—2-position key (with green handle) designated **Atten** and **Loss Pads,** for performing the change-over switching for making gain or loss measurements.

Three—3-position keys, designated **Sender Level,** for controlling the sending level.

Two—rheostats designated, respectively, **Calibrate Galvo** and **Adjust Input,** for calibration purposes.

Sender Circuit

Calibration of Thermocouple—The arrangement of the circuit for calibration of the thermocouple is shown in Figure 2. Direct current is fed from the 24 volt battery terminals through the sending potentiometer, galvanometer shunt, thermocouple heater and **Adjust Input** rheostat in series. The galvanometer is connected across its shunt.

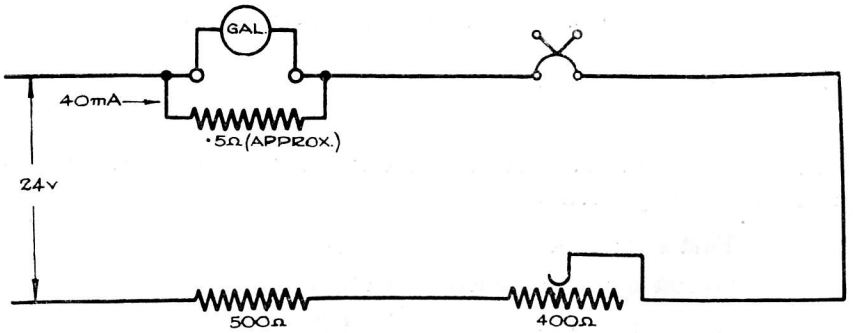

Fig. 2. Adjustment of D.C.

A. 2929, *Issue* 1, *Fig.* 1.

First key on the left	**Couple Cal.**
Second key from the left	**Galvo to Shunt.**
All other keys	**Mid Position.**

Sender Circuit (*Contd*)

The **Adjust Input** rheostat is then adjusted to obtain a reading of exactly 40 mA. (mid-scale) on the meter.

The circuit is then arranged as shown in Figure 3, the galvanometer now being connected in series with the **Cal Galvo** rheostat in the thermocouple output circuit.

First key on the left	**Couple Cal.**
All other keys	**Mid Position.**

The galvanometer should now be reading mid-scale. If it is not giving this reading exactly, the **Cal Galvo** rheostat should be adjusted with a screwdriver to make it do so.

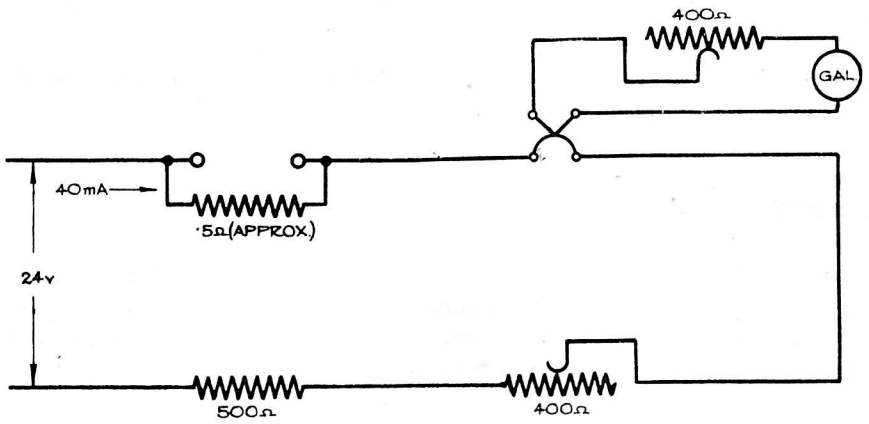

Fig. 3. Calibration of Galvanometer

Drawing A.2929, Issue 1, Fig. 2.

The direction of flow of current through the thermocouple heater should next be reversed and the galvanometer reading checked.

First key on the left	**Couple Cal.**
Second key from the left	**Couple Rev.**
All other keys	**Mid Position.**

If there is any appreciable difference between the readings with the two methods of connection, the **Cal Galvo** rheostat should be adjusted to obtain 40 as the mean reading.

Adjustment of Sending Level—Testing A.C. at the desired frequency should be applied to the **Sender Input** jack of the transmission measuring set.

Sender Circuit (*Contd*)

The tone source and the oscillator amplifier should be switched on and the tone source adjusted to send at the desired frequency. The **T.S. Output** and **O.A. Input** jacks must be connected with a cord, but external connection between the **Sender Input** and **O.A. Output** jacks is unnecessary since these jacks are permanently connected via their inners.

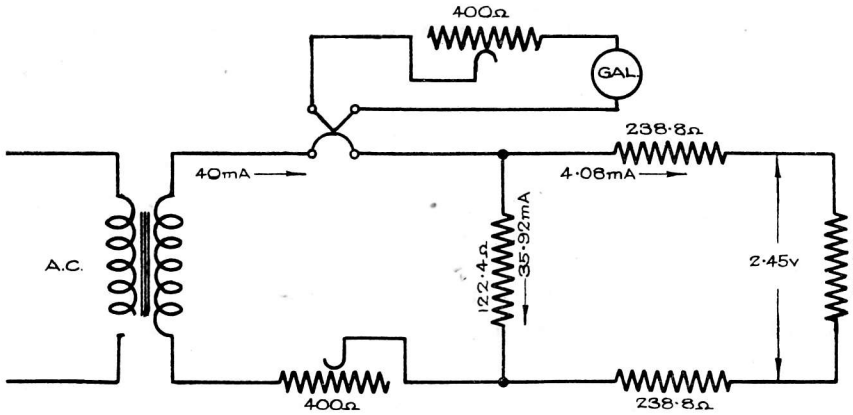

Fig. 4. Calibration of Sending Circuit

Drawing A2929. Issue 1, Fig. 3

With all the keys in their mid-position and with the circuit under test connected to the **Sender Output** jack, the circuit arrangement is as shown in Figure 4, in which the circuit under test is represented by the 600 ohm resistance connected across the sending network.

To calibrate the sender circuit all that is necessary is to adjust the current in the sending network to a value of 40 mA., that is to say, to obtain mid-scale deflection on the galvanometer.

To avoid over-running the oscillator amplifier, the **Adjust Input** rheostat should be set to maximum and the preliminary adjustment made with the **Volume Control** on the tone source; the final adjustment to obtain mid-scale deflection of the galvanometer should, however, be made with the **Adjust Input** rheostat, since this provides a rather finer control.

Levels at the **Sender Output** jack of +10 db., +5 db., zero, −20 db. and −40 db. (with reference to a zero of 1 mW. in a 600 ohm circuit) can be obtained by suitably operating the sender level keys and recalibrating the sender circuit to give mid-scale deflection as follows :—

Sender Circuit *(Contd)*

Zero	All keys in **Mid** position.
+10 db.	Central **Sender Level** key at +10 db., all other keys in mid-position.
+ 5 db.	Left-hand **Sender Level** key at +5 db., all other keys in mid-position.
−20 db.	Left-hand **Sender Level** key at −20 db., all other keys in mid-position.
−40 db.	Central **Sender Level** key at −40 db., all other keys in mid-position.
− ∞	Right-hand **Sender Level** key at ∞, all other keys in mid-position.

The 600 **Ohms to Line** position of the right-hand **Sender Level** key, in which a 600 ohm resistance is connected across the **Gain Input** jack, will not normally be used.

Connection of Output—For sending tone in the normal manner, connection should be made to the **Sender Output** jack, and the level regulated by the operation of the **Sender Level** keys.

Where, as in the case of the transmission equivalent line-up test, it is desired to transmit tone to the 600 ohm input circuit of a ' B ' amplifier at levels separated by steps finer than those provided by the **Sender Level** keys, the output may be taken via the **Att Out** jack and the sending level regulated by suitably setting the keys of the attenuator **AT/2.** The ' B ' input provides the proper termination necessary for the attenuator to ensure accuracy of its readings.

Sender Level keys for sending at zero or any other convenient level.

Key with green handle at **Atten.**

Keys of attenuator for introducing the desired loss.

All other keys at **Mid** position.

In this condition tone is sent (see Figure 1) via the **Sender Output** and **Gain Input** jacks, the inners of which are permanently connected, via the change-over contacts, via the **T.M.S. Att In** and **Att In** jacks, the break contacts of which are permanently connected, and via the attenuator and the **Att Out** jack to the ' B ' amplifier input.

If it is desired to send into 600 ohms, but to retain the attenuator in circuit for the purpose of adjusting the voltage applied to a measuring device with a high impedance input circuit, as, for example, when calibrating a programme meter, the connection should be made via the **Gain Output** jack, across which a 600 ohm termination for the attenuator is provided.

Sender Circuit (*Contd*)

The key settings are as for the case just considered, the circuit being extended via the wiring connecting the break contacts of the **Att Out** and **T.M.S. Att Out** jacks, and the other pair of change-over contacts to the **Gain Output** jack.

The sender circuit may always be considered as a generator of constant e.m.f. and constant internal resistance, namely 600 ohms. When the sender level keys are set to zero, the e.m.f. of the output circuit will be such that the voltage developed across a load impedance of 600 ohms, will be 0.775 volts. The value of the e.m.f. is, therefore, $2 \times 0.775 = 1.55$ volts R.M.S.

It will be observed that the actual power sent into the load will be equal to that indicated by the setting of the sender level keys only where the impedance of the load is non-reactive and has a value of 600 ohms. Where the value differs from 600 ohms, the power sent into the circuit under test will differ from that which would be sent into a 600 ohm circuit, in respect of the reflection loss that occurs at the junction of unmatched impedances (see **Reflection Loss**). In making **tests on lines,** however, no correction need be made for this, since the required line equivalent includes the working reflection losses at each end.

Measuring Circuit

Measurement of 600 ohm Test Loss and Gain. The method described is applicable in the case where both ends of the circuit to be tested are available for connection at the same station. The tone source and amplifier detector are used but it should be observed that it is unnecessary for the amplifier detector to be calibrated for the purpose of this measurement.

For both Loss and Gain measurements the circuit to be tested is connected between the **Test In** and **Test Out** jacks (see Figure 1) and is thus terminated by 600 ohms on both input and output sides when the **Change-over** key is operated to the **Loss Pads** position. Where either the input or output of the circuit under test is earthed on one side, the connection to the **Test In** or **Test Out** jack should be made via a shielded repeating coil, and the result obtained from the measurement should be corrected for the loss introduced by the repeating coil, which can be separately measured. The tone source is adjusted to send at the desired test frequency, which in the case of simple gain or loss measurements will normally be 1,000 c/s. The galvanometer is switched to read in the output circuit of the amplifier detector.

Loss measurements should be made with the input level adjusted to a value approximately equal to that normally present under working conditions in the input circuit of the piece of apparatus under test. Gain is normally specified for amplifiers with their **volume control on maximum.** To avoid over-loading the amplifier, therefore, the input level must normally be less than that present under working conditions in order to compensate for the increase in gain beyond the normal setting. When adjusting the sending level it should be remembered that half of the loss introduced by the **Loss Pads** is included between the **Sender Out** and **Test In** jacks.

Measuring Circuit (*Contd*)

The method in both types of measurement is similar, since when gain is to be measured this is first converted into loss by suitable operation of the **Loss Pads** key. Tone is sent via the **Loss Pads** branch of the measuring circuit and the circuit under test, and the level switches of the amplifier detector are set so as to obtain mid-scale deflection. The attenuator is set so as to introduce maximum loss. Then, without altering the sending level or disturbing the setting of the amplifier detector, the change-over switch is operated and the attenuator adjusted to obtain mid-scale deflection as before. The attenuator setting will indicate the net loss in the **Loss Pads** branch of the measuring circuit.

In the case of a **loss** measurement, seeing that the only loss in the **Loss Pads** branch is that introduced by the circuit under test, the attenuator reading will be the required 600 ohm test loss.

In the case of a **gain** measurement, this reading will denote the overall loss in the **Loss Pads** branch, from which the gain of the circuit under test can be derived by taking the difference between the loss indicated by the setting of the **Loss Pads** key and that indicated by the setting of the keys of the attenuator. Thus, if the loss introduced by the **Loss Pads** is x db., and that introduced by the attenuator is y db., the gain of the circuit under test is $(x-y)$ db.

A slight modification of the foregoing procedure is necessary in order to enable the 600 ohm test gain of an amplifier to be measured, where this is **greater than 60 db.** If such an amplifier is connected between the test jacks there will be a gain instead of a loss in the **Loss Pads** branch of the transmission measuring circuit, even when the **Loss Pads** key is thrown to the **60 db.** position. In this case, when the **Change-over** key is thrown to the attenuator branch it will not be possible to obtain a balance because, even with the whole of the attenuation out of circuit, the output will be too low. The gain of the amplifier can, however, still be measured, by using an increased sending level when the **Change-over** key is in the **Atten** position, and by adjusting the result accordingly.

For example, a sending level of -40 db. can be used when the **Change-over** key is in the **Loss Pads** position and, assuming the gain to be measured does not exceed 80 db., this can be increased to -20 db. when the key is in the **Atten** position and a balance obtained by adjusting the attenuator. If in a particular case the attenuator reading were 13 db., we should have a net gain in the Attenuator branch of the circuit of $(20-13) = 7$ db. The gain of the amplifier would then be given by adding this to the 60 db. represented by the loss introduced by the loss pads, giving 67 db. as the gain of the amplifier.

The voltage gain of an amplifier connected as under normal working conditions (**working voltage gain**) will only be equal to the 600 ohm test gain if the input impedance of the amplifier and also the load into which the amplifier normally works are both 600 ohms. The voltage gain of an amplifier for any condition of working can, however, be calculated from the 600 ohm test gain.

Summary of Operations

Calibration of Sender Circuit

(1) Switch on Tone Source, Oscillator Amplifier and Amplifier Detector.

(2) Adjust Tone Source.

Set **Frequency** dial to zero.
Adjust **Zero** dial to give minimum frequency of beats on detector feed milliammeter.
Set **Range** key and **Frequency** dial according to calibration chart for required frequency.
Set **Volume Control** at minimum.
Connect **T.S. Out** to **O.A. In.**

(3) Adjust Transmission Measuring Set.

(*a*) Adjust D.C.

Key to **Couple Cal.**
Key to **Galvo to Shunt.**
All other keys in mid-position.
Adjust Input to give mid-scale reading.

(*b*) Calibrate Thermocouple.

Key to **Couple Cal.**
All other keys in mid-position.
Adjust Galvo to give mid-scale reading.
Key to **Couple Rev** and check reading.
(If this is not mid-scale, **Adjust Galvo** to give 40 as the mean reading).

(3) (*c*) Calibrate Sender Circuit.

Set sender level keys for desired level (see *d*).
Adjust **TS Volume Control** and **Adjust Input** to give mid-scale reading.

(*d*) Send desired level into 600 ohms.

Level Required	*Sender Level Keys*
Zero	All at mid-position.
+10 db.	Central key at +10 db., others at mid-position.
+5 db.	Left-hand key at +5 db., others at mid-position.
−20 db.	Left-hand key at −20 db., others at mid-position.
−40 db.	Central key at −40 db., others at mid-position.
− ∞	Right-hand key at ∞, others at mid-position.

N.B.—The calibration of the sender circuit must be checked for each setting.

Summary of Operations (*Contd*)

Measurement of 600 ohm Test Loss and Gain

Connect from **In** terminals or jack of apparatus or circuit under test to **Test In.**
Connect from **Out** terminals or jack of apparatus or circuit under test to **Test Out.**

Note :—Connection to earthed circuits to be made via shielded coils.

Connect from **T.S. Out** to **O.A. In.**
Switch on **TS/4, OA/1** and **AD/2.**
Operate T.M.S. (left-hand) key to **Galvo to Meas Cct.**

Loss Measurements	*Gain Measurements*
Set **Loss Pads** key for **zero** loss.	Set **Loss Pads** key to introduce a loss greater than the gain of the circuit under test, i.e. to either −30 or −60.

Set attenuator to give maximum attenuation (all keys thrown).

Adjust tone source to send at the desired test frequency.

Adjust sending level to a value approximately equal to that present under normal working conditions at the input of circuit under test.	Adjust sending level to a value exceeding that present under normal working conditions at the input of the circuit under test, by approximately half the value of the loss introduced by the loss pads.

Operate key (green) to **Loss Pads.**

Adjust **Input Level** dials of **AD/2** to give mid-scale deflection on meter.

Operate key (green) to **Atten.**

Operate keys of attenuator **AT/2** to obtain mid-scale deflection.

The loss of circuit under test is then equal to that introduced by the attenuator.	Read gain of circuit as follows :— Let x=loss introduced by **Loss Pads,** and y = loss introduced by **AT/2.** Then gain = $(x - y)$ db.