Section 5J

TRAVELLING WAVE TUBES

This section refers to forward wave, O type, travelling wave signal or power amplifiers (of output power not exceeding 100 watts, for c.w. or pulsed operation where applicable) having either permanent magnet, electromagnetic or electrostatic focussing.

The general test conditions shall apply to all valves unless otherwise specified in the test specification, but the individual tests (Section 6) contained herein shall apply as and when specified in the Test Specification. If significant differences occur between the test figures obtained by the manufacturers and those obtained at appropriate Service Establishments, the Approving Authority will provide an agreed correction for the guidance of Inspecting Officers.

1. Definitions

1.1 Valve For the purpose of this section the term "valve" in the test clauses, relates to the travelling wave tube as supplied by the manufacturer to meet the appropriate test specification.

1.1.1 Packaged. A term used to describe a valve permanently incorporating the focussing system and r.f. terminals (see Paragraph 1.13).

1.1.2 Encapsulated. A valve having an outer sleeve (capsule) integral with the travelling wave tube to protect the inner envelope from mechanical damage. This may or may not include the r.f. terminals (See Paragraph 1.13).

1.1.3 Mount. The additional focussing equipment and/or r.f. terminals necessary to operate the valve as a travelling wave amplifier but excluding the requisite power supplies.

1.2 R.F. Power Input The r.f. power that would be delivered into a matched load substituted for the r.f. input terminal (see Paragraph 1.13 below).

1.3 R.F. Power Output The r.f. power, having the same frequency as the power input, which is delivered into a matched load at the r.f. output terminal (see Paragraph 1.13 below).

1.4 Gain The ratio of r.f. power output to r.f. power input.

1.5 Small Signal Gain The gain obtained as the input level tends to zero. Unless otherwise specified this is understood to be the gain when the r.f. power output is at least 10 dB down on the specified saturated power output.

1.6 Synchronous Helix Potential The Helix potential giving maximum small signal gain at a given frequency.

1.7 Saturated Power The first maximum value of r.f. power output as the r.f. power input is increased.

1.7.1 Synchronous Saturated Power. The saturated power obtained at synchronous helix potential.

1.7.2 Working Saturated Power. The saturated power obtained either at a specified absolute value of helix potential other than synchronous or at a specified difference from synchronous helix potential, in the specified working conditions.

1.7.3 Maximum Saturated Power. The largest value of saturated power obtained by adjustment of both helix potential and power input at a given frequency.

1.8 Phase Sensitivity The change of phase of the output signal with reference to the input signal, for a specified change in electrode potentials or input signal level.

1.9 Spurious Oscillations Unwanted coherent oscillations occurring under the specified conditions.

1.10 Cold Tests Tests in which electrode voltages are not applied. (The heater may be left on unless otherwise specified).

1.11 Hot Tests Tests in which the valve is operating under specified conditions.

1.12 Cathode Pre-Heating Time The time which must elapse after the application of full heater voltage before the commencement of application of electrode voltages which result in a flow of current from the cathode.

1.13 R.F. Terminals The specified input and output connectors which may be either integral with the valve or the approved mount.

1.14 Input and Output Match The measured voltage reflection coefficient or the voltage standing wave ratio which would occur in a test section fed by a c.w. signal at a reference frequency, and terminated by the r.f. terminal (as defined in Paragraph 1.13). The test section shall consist of a straight uniform length of transmission line or waveguide, whose cross section has the dimensions specified for the r.f. terminal. Where the dimensions of the r.f. terminal are not specified the dimensions of the test section shall be equal to the nominal dimensions of the input/output of the specified waveguide coupling. In the case of an r.f. plug or socket input/output, the test section shall be terminated by an appropriate mating plug or socket.

Precautionary Note: In certain cases the reflected wave may be equal to or greater than the incident wave from the c.w. source owing to amplified reflections from within the valve. V.S.W.R. measurements are then ambiguous. The measurement of voltage reflection coefficient is, therefore, preferred and in this case the value will be equal to or greater than unity.

2. Electrode Numbering

With the exception of the Helix Collector and Cathode, all electrodes are termed grids and are numbered 1, 2, 3 according to their position relative to the cathode, the lowest number being closest to the cathode. Where two helices are equidistant from the cathode, the lower voltage helix is assigned the lower number.

3. <u>Abbreviations and Symbols</u>

Noise Factor (dB)	F
Gain (dB)	G
Helix Voltage	V hel
Helix Current	I hel
Collector Voltage	V col
Collector Current	I col
Grid Voltages	Vg1, Vg2, etc.
Grid Currents	Ig1, Ig2, etc.

4. <u>Colour Code</u>

The following code is to be used with travelling wave tubes equipped with flying leads.

Body Colour	Tracer Colour	T.W.T. Element
Black	None	Earth, or earthed elements
Yellow	None	Cathode also heater cathode lead if common
Brown	None	Heaters or filament off cathode
Brown	Yellow	Heater internally connected to cathode, if additional to cathode lead
Red	None	Collector
Orange	None	Helix 1
Orange	Green	Helix 2
Orange	Blue	Helix 3
Orange	Grey	Helix 4
Green	None	Grid 1
Blue	None	Grid 2
Grey	None	Grid 3
White	None	Grid 4
Green	Black	Grid 5
Blue	Black	Grid 6
Grey	Black	Grid 7
White	Black	Grid 8

(See Paragraph 2 for electrode numbering)

5. General Test Conditions

5.1. Frequency and Wavelength Where it is desired to convert frequency to wavelength, the value $c = 2.998 \times 10^{10}$ cm/sec. shall be used.

All frequencies shall be within 0.5% of the specified value.

5.2. Reference Point and Polarity of Voltages All voltages (except heaters) shall be specified relative to the cathode.

5.3. Test Equipment

5.3.1. Test Solenoid or Permanent Magnet Assembly. All mounts (see Paragraph 1.1.3.) shall be those specified and/or approved by the Design Authority. The use of these mounts is implicit in all tests contained in this section.

5.3.2. Mismatch. Except where a mismatch is specified, the voltage reflection coefficient of all test equipment shall not normally exceed 0.1 at the specified frequency. Where this is not practicable, the Approving Authority will provide an agreed correction for the guidance of Inspecting Officers.

5.4 Power Supplies

5.4.1. Supply Voltages. Where d.c. h.t. supply voltages are specified these shall be within ± 2% of the specified value.

5.4.2 Stability (long term variation) and Ripple (short term variation) Unless otherwise specified the various test voltages and currents shall not exceed the following:-

Helix Voltage	Stability better than ± 0.5% Peak to peak ripple less than 0.5%
Collector Voltage	Stability better than ± 2% Peak to peak ripple less than 1%
Other Grid Voltages	Stability better than ± 1% Peak to peak ripple less than 0.1%
Solenoid Current	Stability better than ± 5% Peak to peak ripple less than 2%

6. Electrical Tests

6.1 Small Signal Gain (1.5) The power gain shall be measured using one of the following methods:-

Method I. The valve shall be operated under the specified conditions in a circuit equivalent to that shown in FIGURE 1A. The switches shall provide an isolation of at least 20 dB more than the gain of the valve under test (e.g. if gain is 20 dB the cross talk ratio shall be at least -40 dB). The switches shall be turned to Position 1 and the level adjusted to give a convenient reading on the indicator. The switches shall then be turned to Position 2 and attenuation introduced to give the previous reading on the indicator. The value of attenuation introduced gives the gain of the valve under test.

NOTE: Where 2nd harmonics may affect the result the necessary precautions shall be taken.

Method II The Valve shall be operated in a circuit equivalent to that shown in FIGURE 1B. The directional couplers shall together have a coupling ratio approximately equal to the gain of the valve under test. The signal generator shall be tuned to the specified frequency or the frequency swept in time over the specified frequency band. The ratiometer output shall be monitored by means of a calibrated recorder or indicator.

Method III The valve shall be operated in a circuit equivalent to that shown in FIGURE 1C. The calibrated attenuator and the phase shifter shall be adjusted to provide a null reading on the indicator. The valve shall then be replaced by a section of transmission line and the attenuator and phase shifter re-adjusted for a null reading on the indicator. The value of attenuation introduced gives the gain of the valve under test.

6.2 High Level Gain. The valve shall be operated under the specified conditions in a circuit equivalent to FIGURE 2. The gain of the valve under test shall be calculated from the readings of input and output power monitors, and the value recorded.

6.3 Spurious Oscillations. The valve shall be operated under the specified conditions in a circuit equivalent to Figure 3.

The Directional couplers shall couple less than 10% of the power in the main arm and the receiving system shall have the specified sensitivity and bandwidth. The helix potential shall be swept over the specified range.

One of the shorting plungers shall be adjusted in fixed steps and the noise output observed whilst varying the other shorting plunger. The onset of oscillations will be observed as a marked change in noise level.

6.4 Noise Factor. The Noise Factor shall be measured by one of the following methods, using the Noise Source specified. Methods I and II may be used for noise factors up to 25 dB, but for greater accuracy Methods III and IV are recommended for noise factors greater than 15 dB. The v.s.w.r. of the noise source shall be not greater than 1.2 with noise source on or off. The bandwidth of the receiver shall be less than 10% of the operating bandwidth of the valve under test. Double sideband may be used provided the intermediate frequency does not exceed 2% of the operating frequency. The symbols used in the equations contained in 6.4.1 are as follows:-

n = Excess noise power of the noise source expressed as a power ratio $\frac{T - T_o}{T_o}$

Where T = effective absolute temperature of noise source

$T_o = 290^{o}K$

x = Reading of Attenuator A expressed as a power ratio greater than 1

y = Reading of Attenuator B expressed as a power ratio greater than 1

f = Noise Factor of valve under test expressed as a power ratio greater than 1

f' = Noise Factor of receiver expressed as a power ratio greater than 1

g = Gain of Valve under test expressed as a power ratio.

6.4.1 Noise Factor Methods of Measurement

Method I The valve shall be operated in a circuit equivalent to Figure 4(A). The noise source shall be switched off and the receiver output noted with attenuator B set to 0 dB. The noise source shall then be switched on, attenuator B set to give 3 dB attenuation and attenuator A adjusted to keep the receiver output constant. The reading of attenuator A shall be recorded. Then

$$f = \frac{n}{x} \qquad (1)$$

For the measurement of noise factors greater than n, attenuator B shall be set to a value lower than 3 dB.

Then
$$f = \frac{n}{x(y - 1)} \qquad (2)$$

Alternatively, attenuator A may be omitted. The noise source shall be switched off and the receiver output noted with attenuator B set to 0 dB. The noise source shall then be switched on and attenuator B adjusted to keep the receiver output constant. The reading of attenuator B shall be recorded. Then

$$f = \frac{n}{y - 1} \qquad (3)$$

Method II This is basically Method I but using an I.F. attenuator.

The valve shall be operated in a circuit equivalent to Figure 4(B). The appropriate procedure stated in Method I shall then be followed.

The general equation, equivalent to equation 2 above is then:-

$$f = \frac{n}{x(y - 1)} - \frac{f' - 1}{g} \qquad (4)$$

Method III The valve shall be operated under the specified conditions in a circuit equivalent to Figure 4(C). With the noise source on, the switch shall be turned to Position 1 and the receiver output noted. The switch shall then be turned to Position 2 and the attenuator A adjusted to keep the receiver output constant. The reading of attenuator A shall be recorded. Then

$$f = \frac{nx + 1}{g} \qquad (5)$$

Method IV Alternatively, the low noise methods specified in Methods I and II may be used in conjunction with a suitable amplifier to increase the output of the noise source. In this case the excess noise, corresponding to n of equation (5) is $n' = g'(n + f'') - 1$ where g' is the gain of the amplifier used to increase the noise power and f'' its noise factor.

6.5. Cold Attenuation (1.10) The insertion loss shall be measured in a circuit equivalent to Figure 5. The electrode voltages shall not be applied. The switches shall be turned to Position 1 and the input level adjusted to give a convenient reading on the indicator. The switches shall then be turned to Position 2 and attenuation introduced to give the previous reading on the indicator. The value of attenuation introduced gives the cold attenuation of the valve under test.

NOTE: Where 2nd harmonics may affect the result the necessary precautions shall be taken.

6.6 Hot Cut-off Loss (1.11) The valve shall be operated under the specified "cut-off" conditions, and procedure of measurement stated in Paragraph 6.5 shall be applied. The maximum input shall be specified.

6.7 Cold Input Match, Cold Output Match and Hot Input Match These measurements shall be made with the valve in a circuit equivalent to Figure 6. The second harmonic filter may be required only in the case of the hot match tests. The directional couplers may be replaced by a standing wave indicator.

6.8 Hot Output Match With the valve operating under the specified conditions the hot output match shall be measured using one of the following methods as applicable. Method I usually measures the hot match at small signal conditions, while Method II can be used to measure the hot match under power conditions.

Method I This is the reflectometer method as specified for the Hot Input Match Test in Paragraph 6.7 above.

Method II This is a "ripple" pipe method. The valve shall be operated under the specified conditions in a circuit equivalent to Figure 7.

The height of the fine structure ripple observed on an oscilloscope shall be used to obtain the reflection coefficient.

A correction factor shall be applied to the reflection co-efficient to account for:-

(i) The loss in the ripple pipe (two directions)

(ii) The loss in power which occurs through the directional coupler (two directions).

The ripple pipe shall be of sufficient length to ensure that its "ripple" is distinguishable from variations in reflection. The directional coupler shall have a coupling ratio not less than 10 dB down.

Alternatively, calibration of the oscilloscope shall be effected by introducing a known mis-match at the output of the valve under test.

SCHEMATIC DIAGRAMS FOR R.F. MEASUREMENTS

SMALL SIGNAL GAIN TEST

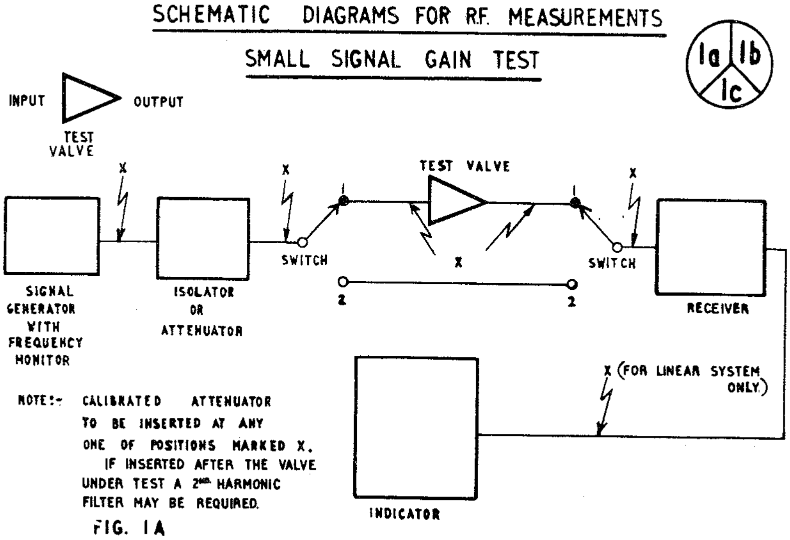


FIG. 1A

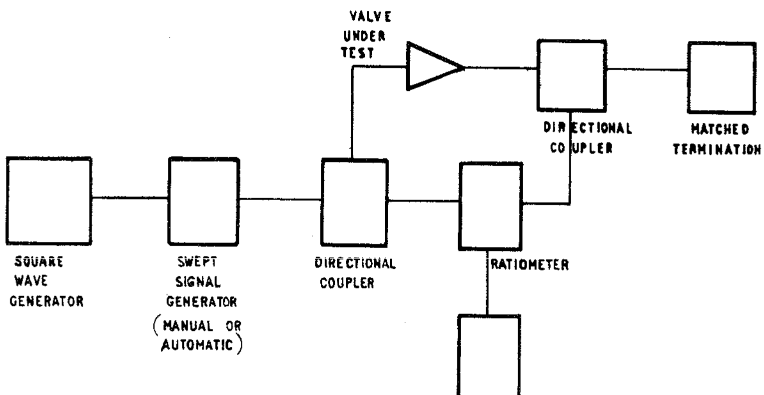


FIG 1B

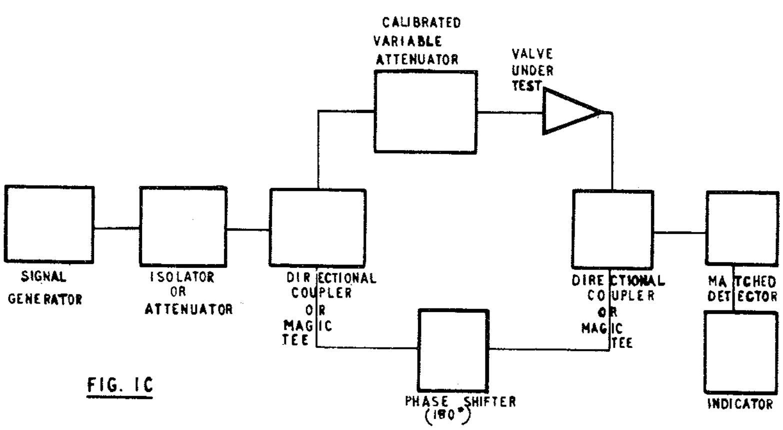


FIG. 1C

SCHEMATIC DIAGRAMS FOR R.F. MEASUREMENTS

HIGH LEVEL GAIN TEST

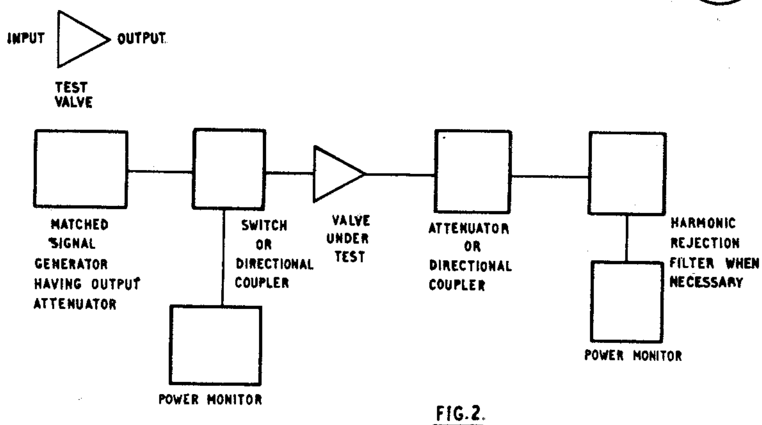


FIG. 2.

SPURIOUS OSCILLATIONS TEST

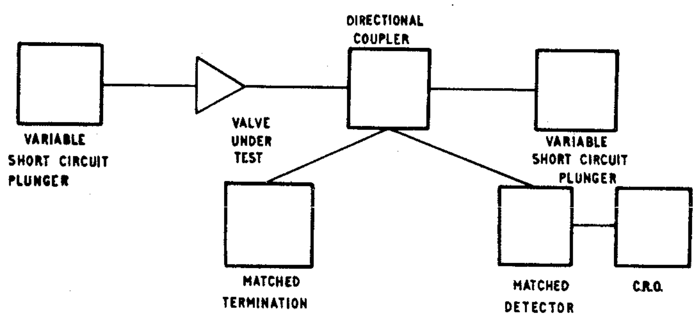
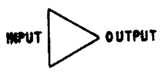


FIG. 3.

SCHEMATIC DIAGRAMS FOR R.F. MEASUREMENTS
LOW NOISE FACTOR TESTS



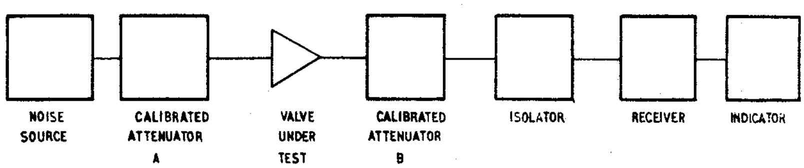


FIG. 4A

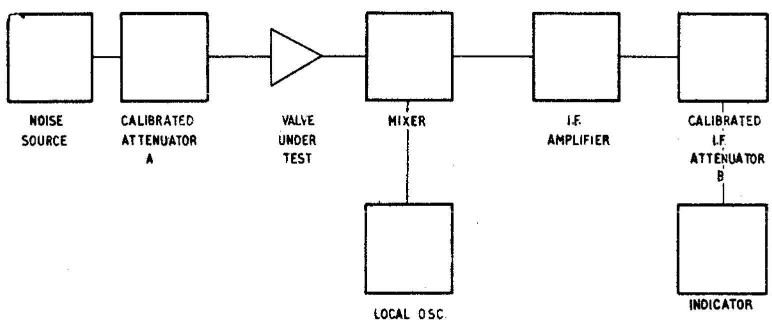


FIG. 4B

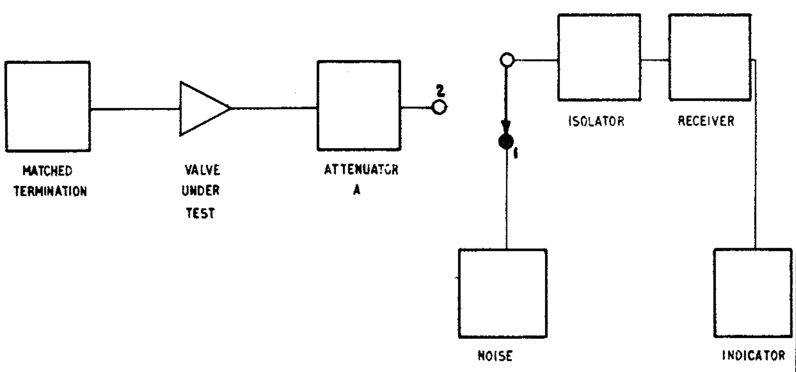


FIG. 4C

SCHEMATIC DIAGRAM FOR R.F. MEASUREMENTS.

INSERTION LOSS TEST MEASUREMENTS.

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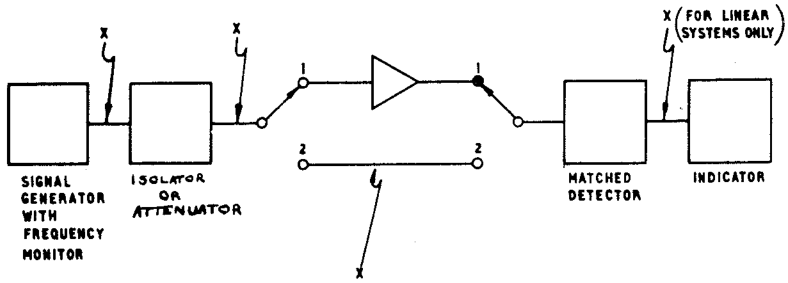

NOTE.
CALIBRATED ATTENUATOR TO BE INSERTED AT ANY ONE OF POSITIONS MARKED X.
IF INSERTED AFTER THE VALVE UNDER TEST A 2ND HARMONIC FILTER MAY BE REQUIRED.

FIG. 5.

COLD INPUT MATCH, COLD OUTPUT MATCH AND HOT INPUT MATCH TESTS.

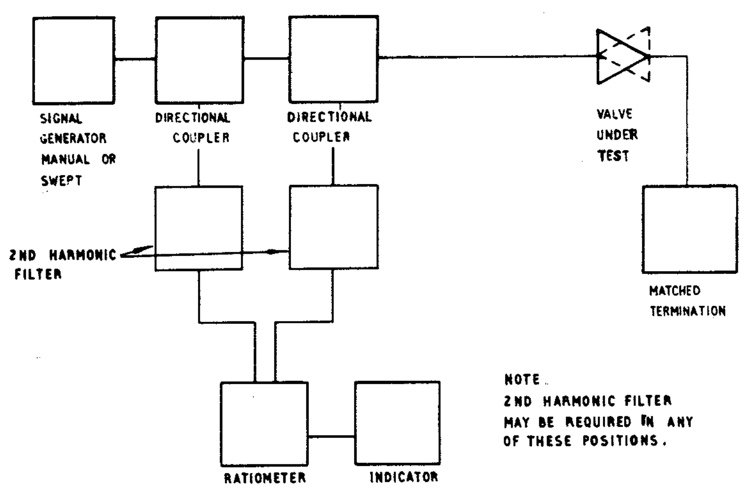

FIG. 6.

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SCHEMATIC DIAGRAMS FOR R.F. MEASUREMENTS
HOT OUTPUT MATCH TEST

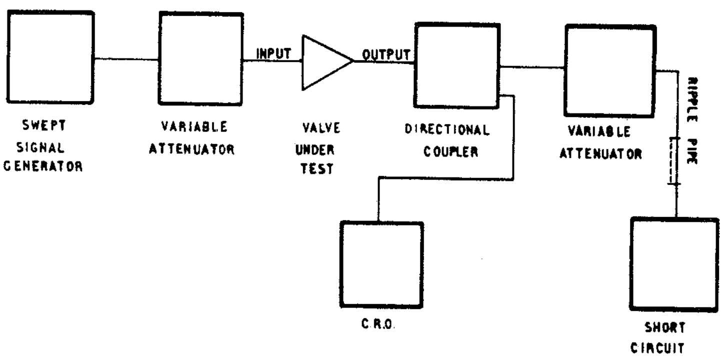

FIG. 7