RADIOTRONICS

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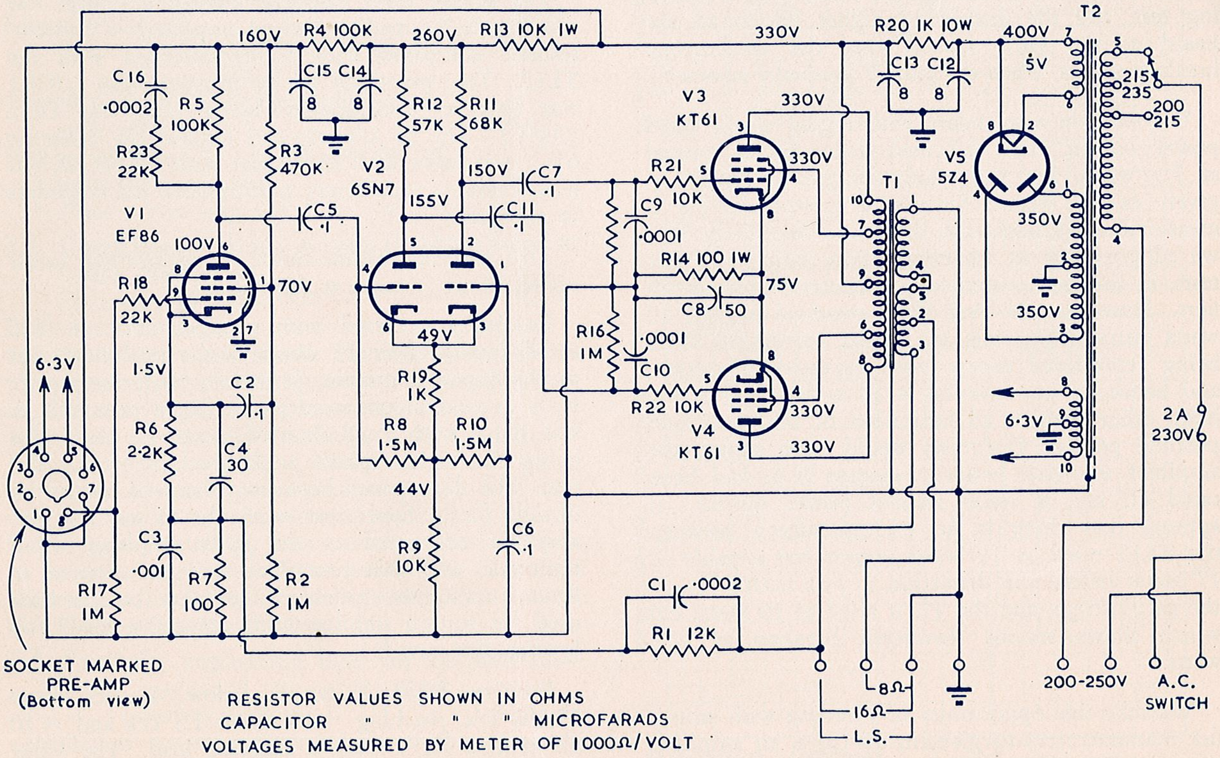
LABORATORY REPORT ON LEAK TL10 MAIN AMPLIFIER

By F. Langford-Smith

The Leak TL 10 Amplifier is a less expensive version of the TL12 and its performance is naturally not so brilliant. It is, however, quite a nice little amplifier for anyone to own.

The specified total harmonic distortion is 0.1% at 7.5 watts at 1000 c/s. Our measured value, however, was 0.32% at 7.5 watts, rising to 0.94% at 10 watts. At lower levels the distortion was principally second harmonic, 0.12% at 2 watts and 0.17% at 5 watts. Another amplifier of the same model was tested, and this showed better performance at low levels — second harmonic 0.13% at 5 watts, 0.65% at 2 watts and 0.045% at 1 watt.

The UL operation of the output stage results in substantial percentages of high order harmonics up to the 13th (and probably still higher, although no measurements were made beyond the 13th harmonic). This effect occurs not only at full load and overload, but also at lower levels — see Item 14 for details. As a consequence, total harmonic distortion is not a true indication of the actual distortion heard by a listener, and some weighting is necessary before the measured distortion can be used to compare say UL and triode operation. In the writer's opinion, based purely on the harmonic measurements, 0.1% THD with UL operation is more objectionable than 0.25% TDH with Class A triode operation.



CIRCUIT DIAGRAM OF TL/10 AMPLIFIER

The ratio of these two figures (say from two to three times) is, of course, only a matter of opinion, but there is no denying the fact that if two amplifiers have the same measured THD and one has substantial percentages of high order harmonics at full power output and the other has not, the former is less objectionable on a listening test.

The opinion expressed in the previous paragraph is largely substantiated by the two weighted forms of distortion. Taking the figures for maximum rated power output in each case, the TL12 with a triode stage has an ordinary weighted figure (WHD) equal to 1.2 times that of THD, while the TL10 with UL operation shows WHD equal to 2.9 times THD, giving a ratio of 2.4:1. Even more significant is the ratio of the Special Weighted figure (SWHD) to THD which is 1.8 for the TL12 (triode operation) and 10.9 for the TL10 (UL operation), giving a ratio of 6:1. This is further substantiated by the non-linearity above about 7 watts.

A serious shortcoming of the TL10 is the sudden overload characteristic. For example, at 1000 c/s the total harmonic distortion is less than 1% at 10 watts, but rises to 18% at 10.5 watts. A second amplifier which we tested only reached 9.5 watts before this same sudden overloading occurred. On the oscilloscope, the waveform breakup is also quite sudden, and the inevitable flat-topping is accompanied by sharp kinks in both sides of the sinewave. The effect is also sharply marked by a listening test, and the distressing higher harmonics are heard at the same instant that the oscilloscope breakup occurs, when the gain is gradually advanced.

We were in a quandary with regard to the rated power output. The specified distortion is quoted at 7.5 watts, but the maximum power output is given as 10 watts. Since the latter was for a measured total harmonic distortion less than 1%, we adopted this as the rated power output for our tests, in line with common practice for most amplifiers. However, the ever rapid overload beyond 10 watts virtually prevents any power beyond 10 watts being reproduced except with excessive distortion, and hence, in our opinion, a 10 watt rating is too high, other than as an indication of the maximum possible power. Our tests would have shown the amplifier to much better advantage if it had been rated at, say, 8 watts normal power output. It appears that there is no correspondence between the TL12 rated at 12 watts output but capable of 17 watts before the distortion is just noticeable on the oscilloscope, and the TL10 rated at 10 watts but which shows serious waveform breakup at 10.5 watts.

We take this opportunity of pleading with amplifier manufacturers to give, in all cases, an amplifier normal rating power output, specifying the distortion at this level. If, in addition, they care to quote a maximum power output irrespective of distortion, or a lower power output with a lower value of distortion, so much the better.

The rated power output of 10 watts is obtainable at 30 c/s only with a THD of 7%, or at 55 c/s with a THD of 1.6%.

The frequency limits for THD not greater than 0.5% are 30 c/s to 5000 c/s for 7.2 watts output; if the output is reduced to half this value at the higher frequencies, the upper frequency limit is increased to 10,000 c/s.

The frequency limits for THD not greater than 1% are 30 c/s to about 7000 c/s for 8.5 watts output; if the output is reduced to half this value at the higher frequencies, the upper frequency limit is increased to 15,000 c/s.

The negative feedback as measured by us was 21 db at 1000 c/s, very good at 30 c/s (20 db), but falling badly to 7 db at 15,000 c/s. This is a large contributory element to the rather high distortion at high frequencies.

The effect of unbalanced direct current on the total harmonic distortion is quite severe. At 1000 c/s and 10 watts output the THD rises from 1% to 4.6% as the mismatch varies from 1.2 to 21.2 mA. At 55 c/s and 10 watts output the THD rises from 1.6% to 7% as the mismatch varies over the same range. The low frequency used for this test was increased from 30 c/s, as used for the Leak TL12, to 55 c/s to make the test less severe.

The square wave response showed a typical rise time figure for medium priced amplifiers — 9 microseconds compared with 5 microseconds with the TL12. The overshoot on a resistive load (8%) was however considerably better than the TL12 (34%). The 50 c/s top and bottom tilt (average 6%) was more than twice that with the TL12, but is still quite a satisfactory performance for amplifiers in its class.

The linearity characteristic is apparently linear up to about 7 watts at 1000 c/s.

Instability occurred with a capacitance of 0.16 μF shunted across 15 ohms, with no connections to the input terminals. However, with the square wave generator connected to the input terminals, it was stable with 1 μF shunted across 15 ohms, this being the highest phase angle used by us for this test. The discrepancy between these two results indicated that a fairer test would be to use the preamplifier connected to the main amplifier input terminals, and this procedure will be adopted in future tests (see article "Comments on methods used for testing stability with capacitive load" following this article).

Positive feedback occurs below 4 and above 35,000 c/s, reaching +10 db at 1.5 c/s and +10 db at 150 Kc/s with a resistive load. The value of shunt capacitance selected for our test showed rather better performance than a purely resistive load.

AMPLIFIER TEST FORM

(for use with main amplifiers)

Matched valves and resistive loads used unless otherwise indicated. All a.c. voltages recorded as r.m.s. readings.

Amplifier — Make: Leak.
Model No.: TL10.
Serial No.: 5007. Rated power output 10 W.

Supplied by: Simon Gray (Radio Division).
Output transformer: Leak.
Output valves: As supplied (see below).

	$E_b = E_{c2}$	E_{c1}	I_b	I_{c2}	g_m	P.O.
V_1	310V	−7.5V	42.5 mA	9.77 mA	12,200	
V_2	310V	−7.5V	43.7 mA	9.83 mA	12,400	

1. Square wave test (at 5 Kc/s unless otherwise indicated).
Measured at half rated power output.

1.1. Resistive load

Rise time (10% to 90% of peak-peak voltage) 9 μsecs.
Overshoot (percentage of peak-peak voltage) (average of positive and negative half cycles) 8%
Ringing time 45 μsecs.
(i.e. time for the ringing to die down)
Top tilt* at 50 c/s (percentage of peak-peak voltage) 7%
Bottom tilt* at 50 c/s (percentage of peak-peak voltage) 5%
* After subtracting any tilt in the generator.

1.2. Capacitance shunt across 16 ohms load to cause oscillation 0.16 μF
Frequency of oscillation 95 Kc/s
No connection to input terminals.

1.3. Stability when shock excited by a 5 Kc/s square wave with square wave generator connected directly to input terminals.
1.31 Load short-circuited: Stable
1.32 Load open-circuited: Stable
1.33 Load shunted by a capacitance: stable with any capacitance up to 1 μF

The greater stability when shock excited appears to be due to the lower input impedance (less than 5000 ohms for the square wave generator). See the article elsewhere in this issue.

1.4. Partially capacitive load for further tests
1.42 Capacitance to give worst transient response. 0.25 μF
(oscillation continues over whole of flat top — on verge of instability)
Capacitance of 0.2 μF used in further tests.
Overshoot under these conditions 15%

Ringing time — Ringing continues over whole flat top.

1.5. Purely capacitive load
Oscillates.

2. Frequency response 1.1 c/s to 500 Kc/s.
Measured with constant input voltage to give 50% of rated power at 1000 c/s, down to 20 db attenuation, then increased 10 db for greater values of attenuation. Source impedance less than 10,000 ohms.

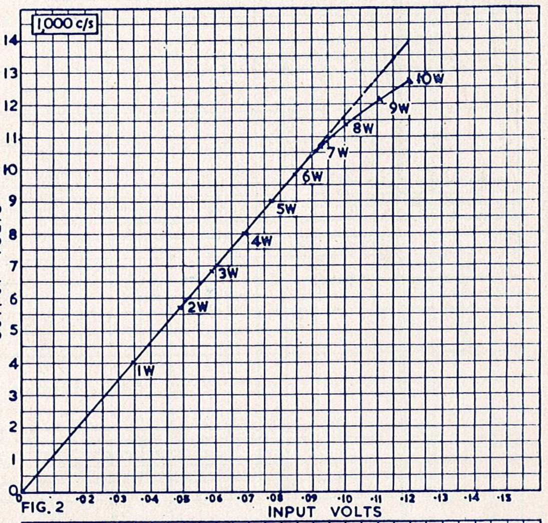
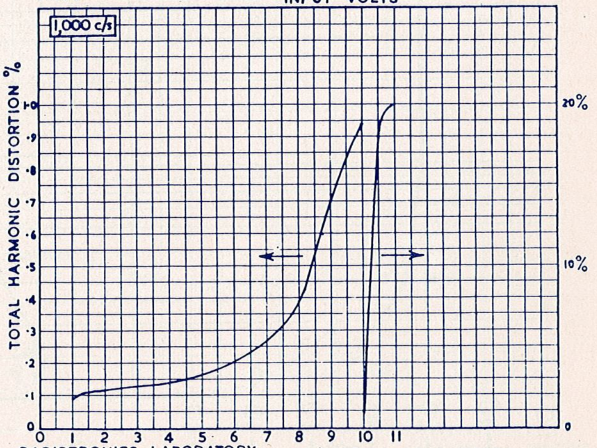
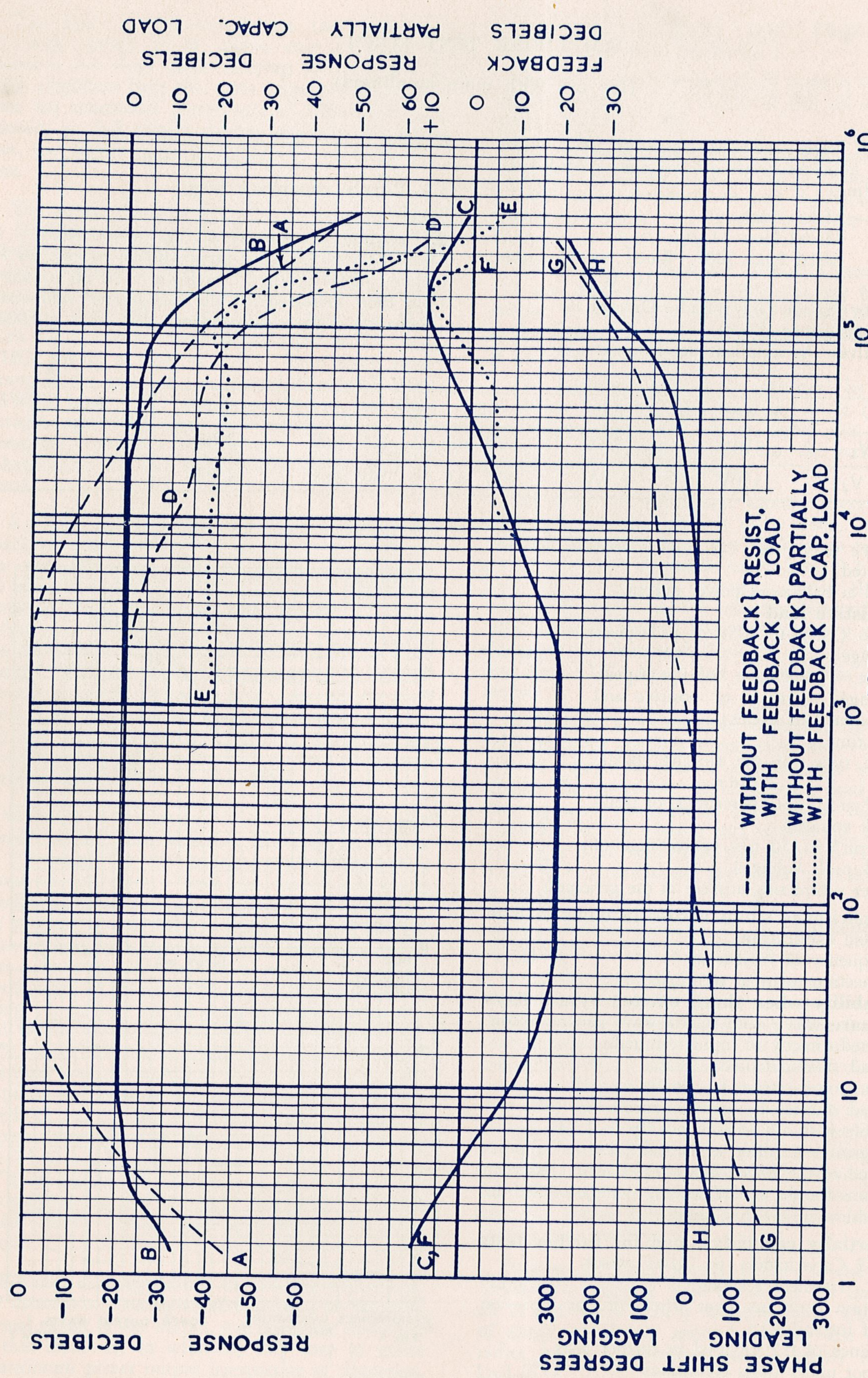


FIG. 2



RADIOTRONICS LABORATORY AMPLIFIER LEAK TL10 FIG. 3 POWER OUTPUT WATTS FORM 2



RADIOTRONICS LABORATORY AMPLIFIER LEAK TL10 FORM 1
FIG. 1

2.1. Resistive load
(A) Without feedback
(B) With feedback
(C) Difference curve (feedback).
Curves A, B and C are plotted in Fig. 1.

Frequency.	30	1000	15000	c/s
Feedback	20	21	7	db

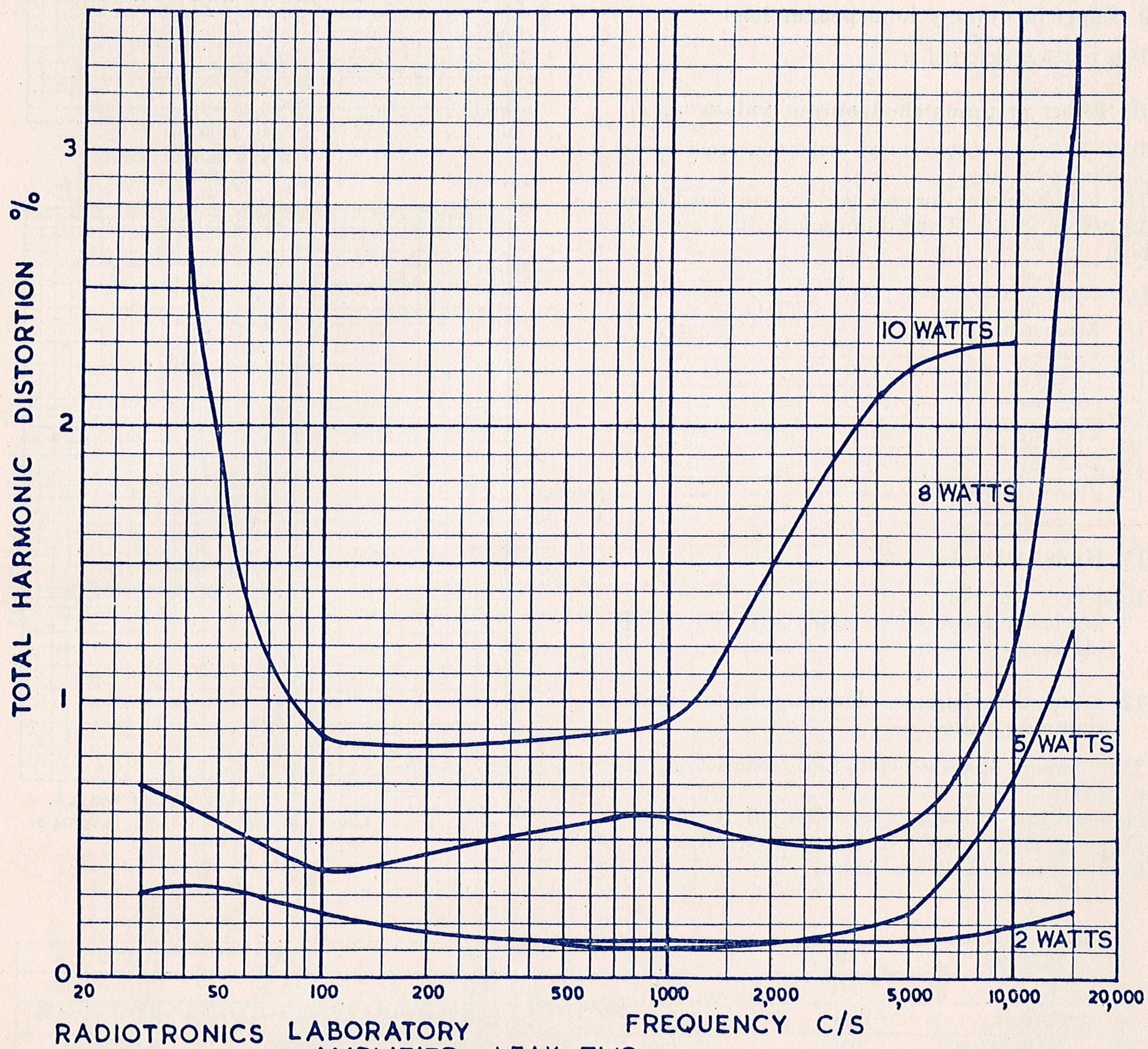
2.2. Partially capacitive load as 1.4 from 1000 c/s to 500 Kc/s.
Shunt capacitance 0.2 μF
(D) Without feedback
(E) With feedback
(F) Difference curve (feedback).
Curves D, E and F are plotted in Fig. 1.

3. Phase shift versus frequency (from 1.1 c/s to 500 Kc/s).
Resistive load
(G) Without feedback
(H) With feedback.
Curves G and H are plotted in Fig. 1.

4. Linearity characteristic (output volts versus input volts with power output marked).
At 1000 c/s; up to overload. Output voltage measured with peak-reading voltmeter. The curve is plotted in Fig. 2.
Input voltage for rated max. power output (10 W) 0.12 V.
At 10W output, the sine wave is just commencing to show a flat top.

5. Total harmonic distortion versus power output
The Wave Analyser was used to measure the individual harmonics at 1000 c/s, following the method for Item 14, from which the THD was calculated. The resultant curve is shown in Fig. 3.

6. Total harmonic distortion versus frequency
THD versus frequency curves for 2, 5, 8 and 10 watts power output, from 30 to 15,000 c/s, are plotted in Fig. 4.
Test frequencies 30, 55, 110, 1000, 5000, 10000, 15000 c/s.



RADIOTRONICS LABORATORY AMPLIFIER LEAK TL10 FORM 3
FIG. 4

7. Intermodulation distortion versus single frequency equivalent power output

(power output based on measured voltage × 25/17) Tests made using Altec-Lansing Intermodulation Tester.
Three curves are plotted in Fig. 5: (1) 40 c/s and 7 Kc/s, (2) 60 c/s and 7 Kc/s, (3) 100 c/s and 7 Kc/s.

8. Ratio of intermodulation distortion to total harmonic distortion

The ratio of IMD at 100 c/s and 7 Kc/s (see 7.3) to THD at 1000 c/s (see 5), is plotted as a curve on Fig. 5. This ratio returns approximately to unity at full power output, emphasizing that this method gives a much poorer indication of actual distortion than THD. This subject is covered in greater detail in Radiotronics for September 1955 pages 104-105 under Item 8.

9. Effect of dummy loudspeaker load

This test was deferred.

10. Effect of unmatched output valves

Total harmonic distortion at maximum rated power output (10 watts):
The low frequency for this test was increased from 30 c/s to 55 c/s as the distortion at 30 c/s was so high.

Mismatch.	THD	
	55 c/s	1000 c/s
1.2 mA	1.6%	1.0
6.2 mA	2.6%	2.1
11.2 mA	4.0%	2.6
16.2 mA	5.1%	3.5
21.2 mA	7%	4.6

11. Hum and noise

Total hum plus noise:
- db below rated power output (10 W) 77 db
- db below 1 watt 67 db

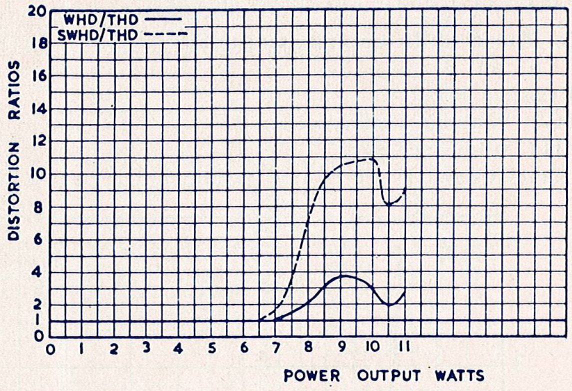
12. Output resistance, damping factor and damping ratio

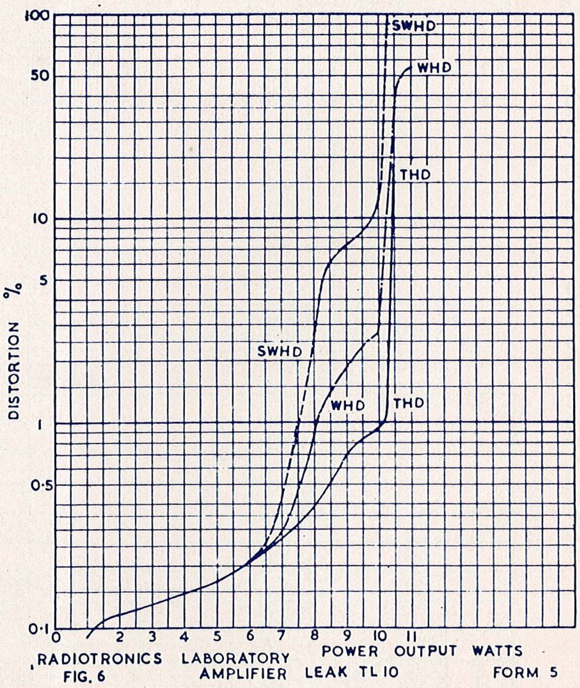
The output resistance (R_{os}) is referred to the secondary.
Nominal load resistance (secondary) $R_{LS}=16$ ohms.
Damping factor (D.F.) is defined as R_{LS}/R_{os}.
Damping ratio (D.R.) is defined

Damping ratio (D.R.) is defined $\dfrac{R_{LS}}{(R_{LS}+R_{os})}$.

(Note: Damping Ratio is preferred to the older term Damping Factor, since it avoids going through infinity to negative values.)

13. Regulation is here defined as the difference between the output voltage unloaded and that with normal load, divided by the unloaded voltage, expressed as a percentage (British definition):
Regulation at 1000 c/s 3.8%





RADIOTRONICS LABORATORY AMPLIFIER LEAK TL10 FORM 5
FIG. 6

Frequency	30	50	100	1000	10,000 c/s
R_{os}	0.9	0.8	1.0	0.6	2 ohms
D.F.	17.8	20.0	16.0	26.7	8.0
D.R.	0.95	0.95	0.94	0.96	0.89

14. Individual harmonics using Wave Analyser

Measured at 1000 c/s resistive load.
Power at which flat top first appears on oscilloscope 10.1 W

In this test, the particular harmonic being measused is attenuated by a parallel-T network, tuned to the harmonic, between the oscillator and the input terminals to the amplifier. By this means, the effect of oscillator distortion is made so low as to be unmeasurable. In the oscillator used for these tests, the only measurable harmonics are the second and third, so that this precaution is not required for higher order harmonics.

In addition, an 1800 c/s high pass filter using air cored inductors and with an attenuation greater than 40 db at 1000 c/s, was connected between the amplifier and the wave analyser.

Details of this method, and the equipment used, will be given in a future issue.

A table showing harmonic percentage appears on the following page.
Harmonics below 0.01% were neglected.

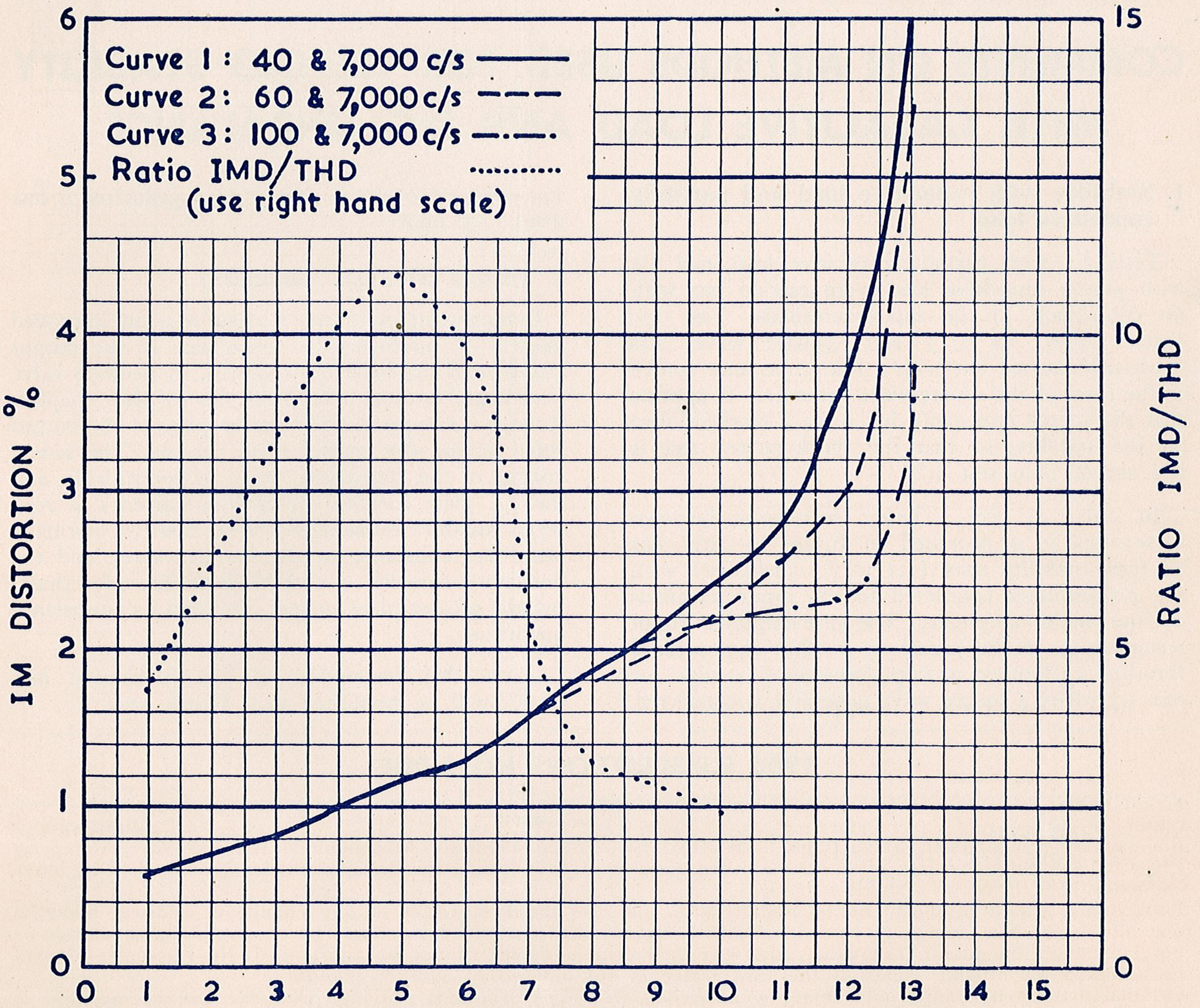
15. Total harmonic distortion using harmonics up to the thirteenth

The three formulæ used for this calculation are given in Radiotronics Vol. 20 No. 9 (September 1955) page 106, equations 1, 2 and 3.

The three curves are shown in the lower portion of Fig. 6 where

THD = total harmonic distortion
WHD = weighted harmonic distortion
SWHD = special weighted harmonic distortion.

Since the TL10 is an ultra-linear amplifier, it is not surprising that the higher harmonics appear from 7 watts upwards and the ratios of the two "weighting" methods show considerable divergences from THD — see the upper portion of Fig. 6.



RADIOTRONICS LABORATORY AMPLIFIER LEAK TL10

FIG. 5 FORM 4

	HARMONIC PERCENTAGE.						
HARMON.	1	2	5	8	10	10.5	11 Watts
2	0.09	0.12	0.17	0.29	0.36	0.38	3.1
3	—	—	0.02	0.08	0.28	0.33	1.0
4	—	—	—	0.06	0.16	0.50	8.2
5	—	—	—	0.18	0.60	16.0	13.1
6	—	—	—	0.03	—	4.3	9.2
7	—	—	—	0.13	0.41	5.9	6.4
8	—	—	—	—	0.03	0.9	2.5
9	—	—	—	0.09	0.30	1.4	0.6
10	—	—	—	—	0.01	1.1	2.1
11	—	—	—	—	0.16	1.1	0.52
12	—	—	—	—	—	0.5	1.5
13	—	—	—	—	0.06	0.05	1.1

COMMENTS ON METHODS USED FOR TESTING STABILITY WITH CAPACITIVE LOAD AND D.C. UNBALANCE

1. Stability with capacitive load and partially capacitive load

Tests 1.2 with partially capacitive load, and 1.5 with purely capacitive load were carried out with no connection to the input terminals. Test 1.3, shock excited by a 5 Kc/s square wave, was necessarily carried out with a low impedance source in the form of the square wave generator. It appears that the source impedance has quite a marked effect on the stability, so that the shock-excited test is less severe than test 1.2.

In order to give a better correlation between these tests it is proposed in future to carry out all these stability tests (1.2 to 1.5 inclusive) with the pre-amplifier connected to the input terminals of the main amplifier. The pre-amplifier input terminals are to be joined by a 4000 ohm resistor forming a dummy pickup impedance, except for test 1.3 where a square wave generator is connected. The impedance of the square wave generator is less than 5000 ohms.

2. Testing with d.c. unbalance

Commencing with the current test, an improved method of producing d.c. unbalance in the output transformer has been incorporated. A pentode valve with negative current feedback has its plate coupled, through a stopper resistor, to the plate of the output valve having the greater plate current. The screen voltage of the "unbalance" valve is controllable, and the d.c. plate current (or cathode current) is read on a suitable milliameter. Since there is normally some d.c. unbalance in the output valves, and the unbalance network is connected to the valve drawing the greater plate current, the total d.c. unbalance quantities.

A detailed description of this "unbalance network" will be published in a future issue.

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Editor .... D. Cunliffe-Jones
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