Integrated Audio Monitor for Home and Studio Use

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This simple and inexpensive piece of audio test apparatus could well become the nucleus of the serious experimenter's own "audio laboratory." Construction is easy because of the use of the basic elements of a standard kit.

Most audio workers, whether professional, hobbyist, or both, find a recurrent need for some means of comparing the actual performance of amplifiers under a variety of conditions. Some of these tests are subjective, and may be conducted by listening to a recording of Koroido Ementado's "Lost Symphony" played through the amplifiers in turn. Others will be more objective, involving various square-wave and sine-wave generators, one or more oscilloscopes, and a host of other instruments, all costly.

For practically all of these tests, a standard speaker, of good-to-excellent quality; an audio-frequency meter; and a power-output meter of some sort are either desirable or essential. For a number of years, the writer has used an 8-in. Electro-Voice speaker, a Heathkit audio-frequency meter, and an audio wattmeter of the same manufacture with results slightly better than the manufacturers would dare claim.

An increasing number of instruments in use and some fundamental limitations of these instruments, in view of the writer's preference for low listening levels, made some changes desirable for operating convenience. After considerable experimentation, an integrated audio monitor was built, embodying on one panel a speaker, a baffle, an audio wattmeter capable of indicating down to less than 0.1 milliwatt, an audio-frequency meter dependable down to the same low power range, and the necessary power supplies and range switches. Performance of this combination has been gratifyingly satisfactory, eliciting several "make me one" requests.

General appearance of the audio panel is shown in *Fig.* 1, the panel being of aluminum, 8¾ by 19 in. The panel plus the cabinet—a gray Bud CR-1741—make a satisfactory baffle at low signal levels, but are not satisfactory for speaker inputs above about six watts. The face of the speaker is protected by a half-hard aluminum grille, procured from a kitchenware supply house.

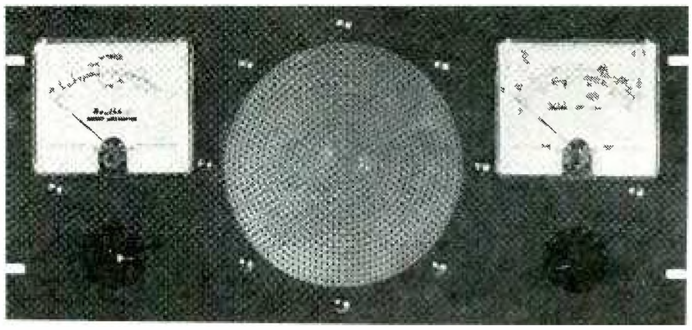

Fig. 1. Front panel view of audio monitor.

The audio wattmeter is mounted at the left, with its range switch directly below; and the audio-frequency meter is at the right, above its range switch.

The audio wattmeter circuit, based on the very satisfactory Heath design, but modified to increase the sensitivity and to protect the instrument pointer from slamming while switching, is shown in *Fig.* 2. Because this circuit is always operated in shunt with the speaker, the original dummy loads are omitted. To facilitate rapid checking of calibration, point six of the range switch is a calibration position. Ranges are shown in Table I.

TABLE I

POSITION	RANGE
1	0.5 milliwatts
2	5.0 milliwatts
3	50.0 milliwatts
4	0.5 watts
5	5.0 watts
6	calibration

A 50-watt position is intentionally omitted, as the speaker won't stand 50 watts, and neither will the local police! To eliminate grounding trouble, the calibration voltage is taken from the plate-power transformer, instead of from the a.c. line, as in the original instrument instructions.

Construction

Construction of the wattmeter, as of the frequency meter, is on two chassis, to allow space for the speaker magnet, as shown in *Fig.* 3. Switches, range resistors, and calibration dropping resistors are mounted on and in the subchassis; meter and switch plate are on the panel; other components are on the main chassis. Interchassis connections are made by means of Jones plugs. Chassis rigidity is secured by use of end brackets.

This audio wattmeter is actually a vacuum-tube voltmeter, with heavy and variable feedback, which measures the voltage across a known load resistor, but is calibrated in watts—a function of the square of the voltage divided by the resistance of the load. The switching mechanism permits the measurement of various voltage ranges without exceeding the normal capabilities of the amplifier (i.e., saturation and cutoff).

Range switching in this type of amplifier produced rather severe pointer slamming during switching, whether or not shorting switches were used. By employing a non-shorting switch on the a.c. supply circuit, and shunting a relay across the power transformer, with its contacts arranged to short the meter when the coil is de-energized, pointer slamming is reduced to a negligible value. The relay, a conventional 115-volt SPST component, was adjusted for quick action by tightening the spring and bending the upper contact down close to the armature contact when it is in closed position. Similar prevention of pointer slamming can be obtained by shunting several thousand microfarads

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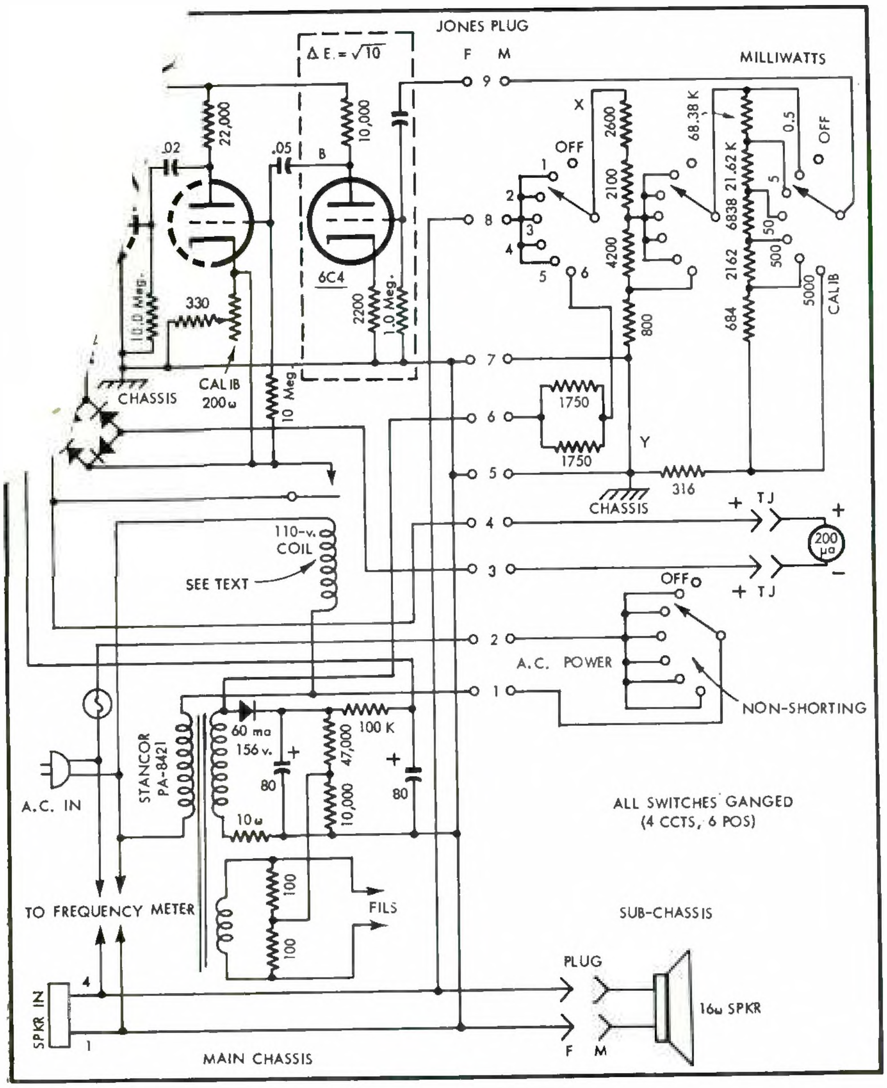

Fig. 2. Circuit of high-sensitivity audio wattmeter.

of capacitance across the instrument movement, but this damps the response undesirably.

The physically large resistors are mounted on the top of the subchassis, and protected from both damage and accidental contact by a punched metal cover, which began life as the bowl of a potato ricer.

The 6C4 amplifier stage in *Fig.* 2, shown enclosed in dotted lines, was added to the monitor in order to get a 0.5-milliwatt range. If this low range is not desired, the points A and B in the figure can be bridged, and all boxed components omitted. This multiplies all range-position values by 10, and requires that the calibration point be shifted one position clockwise on all switches.

This amplifier is intentionally inefficient. To raise the sensitivity of the instrument by a factor of 10, the voltage need be raised only by a factor of the square root of 10, or roughly 3.16, because $W = E^2/R$.

Calibration

Calibration procedure may seem a bit vague from the circuit diagram, *Fig.* 2, because a number of elements contained in the original wattmeter design, but not essential in this specific application, have been omitted. Originally, calibration was set by applying line voltage across a dummy load of 638 ohms, which, in parallel with the impedance-adjusting string (X—Y in *Fig.* 2) made up a total resistance of 600 ohms. When a 115-volt signal is applied across 600 ohms, the power dissipated is 22 watts. To calibrate, when 115 volts is applied across the original instrument, the CALIB control is turned so that the meter reads 22 watts (on the 50-watt range), and all ranges are then in calibration due to the use of precision resistors.

Now, when we apply 115 volts across a dummy load and the impedance-adjusting resistors (X—Y, *Fig.* 2) in parallel, we are also applying the same voltage across the impedance-adjusting string alone, and the dummy load (638 ohms) can be omitted without altering the calibration accuracy. When the power-transformer secondary voltage, with full load, is applied across the adjusting string in series with 875 ohms, the voltage at point X is exactly 115, and the requisite conditions for calibration have been met without the use of a 25-watt dummy load resistor. This voltage should be measured, and the series resistor adjusted if necessary to obtain the right value, as the voltage of the power transformer—under the light load imposed by this circuit—will run slightly over the rated 125.

With the exception of this possibly needed adjustment, all resistors other

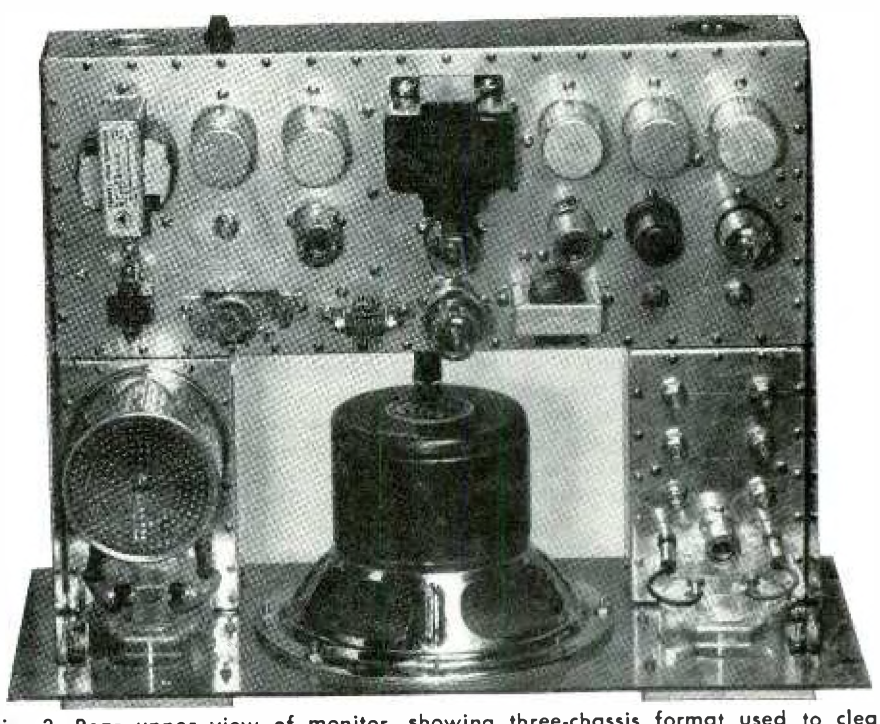

Fig. 3. Rear upper view of monitor, showing three-chassis format used to clear speaker magnet. Wattmeter subchassis is at right, frequency-meter at left, and main chassis at bottom in this view.

than those in the input dividing circuits can be stock 10-per cent items. Resistors in the input dividers should be of one per cent accuracy or better, as are those supplied in the Heath Audio Wattmeter Kit.

This type of audio wattmeter, on the basis of extended tests, is far superior to the older and cruder diode type,[1] and at least equal, for this specific application, to the dual-triode wattmeter described by Seely.[2]

[1] R. L. Ives, Diode wattmeter construction, *Radio-Electronics*, Vol. 26, No. 2, Feb. 1955, pp. 38–39.

[2] Samuel Seely, *Electron Tube Circuits*. New York: McGraw-Hill, 1950, p. 486.

Frequency Meter

The audio-frequency meter, whose components are grouped on the left side of *Fig.* 3, is also built on two chassis, with the critical elements and controls on the small subchassis, and the less critical components, including power supply, on the main chassis. The circuit is a modification of the well-known amplifier-limiter-rectifier cycle counter which is used in the Heathkit Audio Frequency Meter and a number of other similar instruments. Although many Heath parts are used in this assembly, the circuit differs from the Heath circuit by the addition of an amplifier, so as to lower the minimum voltage to which it will respond dependably; the inclusion of a calibration check position on the range switch, to permit instantaneous operation checks if desired; and by elimination of all frequency ranges above 30,000 cps. (I can't hear that high, and the speaker will not respond well at such high frequencies). The circuit is shown in *Fig.* 4.

Operation of this frequency meter consists of amplifying the initial infed signal, equalizing the pulses, and then counting them. Amplification is done in the first three tubes. The input 12AU7 is an almost-linear amplifier, the first

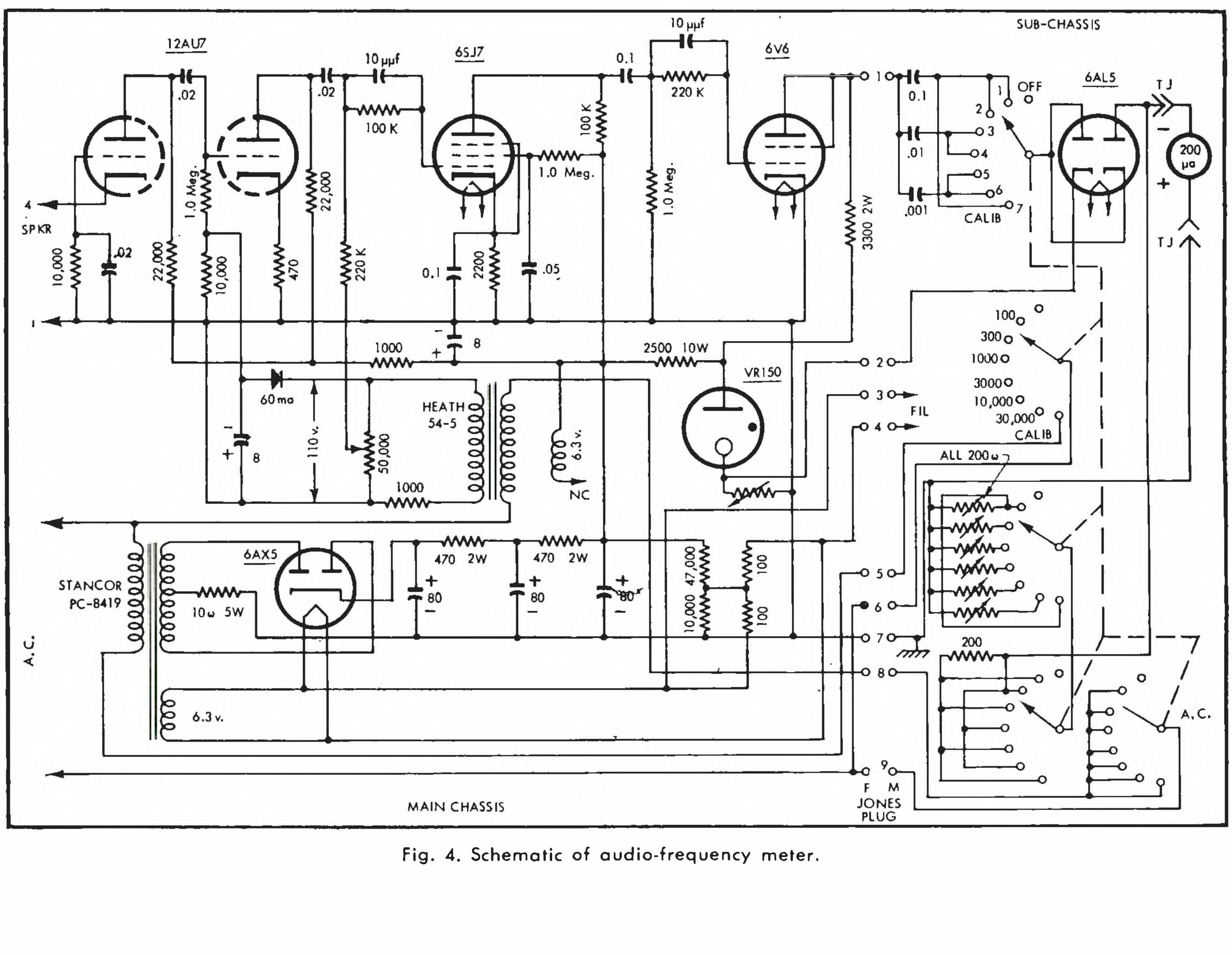

Fig. 4. Schematic of audio-frequency meter.

half being cathode driven, the second half conventional. On very strong signals, a small negative bias is produced on the first grid, due to grid rectification. The 6SJ7 functions as a standard amplifier on weak signals, and as a limiter on strong signals, due to the high grid-circuit resistance and the somewhat "starved" plate and screen supplies. The last tube in the amplifier, a triode-connected 6V6, operated at a reduced and regulated plate voltage, acts almost solely as a limiter. As a result, output of the amplifier portion of the frequency meter consists of square waves, of uniform amplitude, regardless of the input amplitude.

These square waves are differentiated across the capacitor in the output, then rectified in the 6AL5, and the rectified current is passed through the meter. In consequence, the meter indication is a true measure of input frequency.

Contact potential in the dual diode circuit is bucked out by the drop across the resistor in the return of the voltage-regulator tube so that the meter reading is a true measure of frequency, instead of frequency plus contact potential. This correction is made with the input shorted, and the 1000-ohm resistor is adjusted so the meter indicates zero.

Calibration of the lowest range is accomplished by switching to the calibration position. Here, the second half of the 12AU7 is biased off, and an a.c. signal (60 cps) is injected into the grid of the 6SJ7. The voltage of this signal is set at about 20 (not critical), and the resistor for the lowest range (0–100 cps) is set at 60. Other ranges can be calibrated by use of an audio oscillator, by a "counting up" procedure, or by comparison with a precision frequency meter.

Power Supply

Power supply here is a conventional full-wave rectifier system, with a two-stage R-C filter. Filaments are run at a moderate positive bias with respect to ground to eliminate diode hum injection. This is necessary only at very low signal levels, and need be applied to the first triode only. It is regarded as standard to connect a large capacitor from filament center tap to ground, but oscilloscope tests showed that it made no difference in this circuit.

All of the components in this frequency meter are stock items, and no improvement in performance is likely to result from the use of "gold plated" components. Filter capacitors are very much larger than is initially necessary, so that gradual loss of capacitance with ageing will not lead to a sudden instrument failure. Life of these capacitors (Mallory FP149) at voltages not exceeding 350 is in excess of five years in normal station operation. Tube life is considerably more than 7000 hours in this type of service, so that the use of "special red" and "premium" tubes would be painting the lily.

Panel and above-chassis construction, illustrated in *Figs.* 1 and 3, is simple and straightforward. Tube shields are used as hold-downs on miniature tubes, but are not electrically necessary. Meter connections are made with tip jacks as a matter of servicing convenience. Under-chassis construction, shown in *Fig.* 5, is likewise quite simple. Components are anchored in place with more care than is usually employed, to prevent

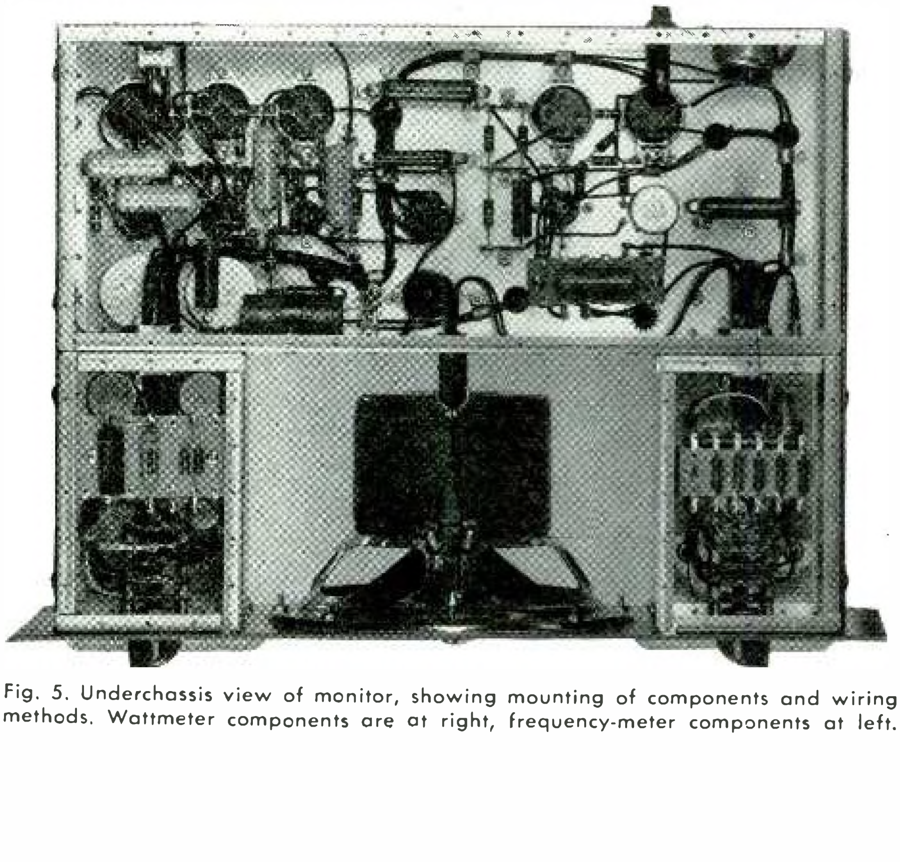

Fig. 5. Underchassis view of monitor, showing mounting of components and wiring methods. Wattmeter components are at right, frequency-meter components at left.

rattle at power outputs up to fifteen watts. Electrolytic filter capacitors are mounted in plug-in type sockets (Cinch 2-C-7) to facilitate replacement. In consequence, probably in accord with Finagle's Third Law of Electronics (components easy to replace never fail), none of them have needed replacing!

Because of numerous unhappy experiences with "improved" plastic insulation, all wiring is with waxed cotton-braid insulated stranded wire (Belden 8844), which has been consistently satisfactory over a period of years. Wire is anchored in place at strategic points by use of cable clamps, to prevent both vibration and shifting. Connections to plugs are insulated with two short lengths of telescoped sleeving, a technique borrowed from the Signal Corps.

Sheet metal screws in the chassis assembly were omitted, and all plate-holding screws are 4-40 binding heads, tapped into the chassis rails. Liberal use of tie terminals assures that the smaller components will not loosen with age. Bottom plates are used with all three chassis, for both electrical and mechanical shielding.

Performance of this audio monitor panel is about all that can be desired for an assemblage of "standard" speaker, wattmeter, and frequency meter. By its use, evaluation of new amplifiers and other audio components is made more objective, and the checking procedure is greatly simplified by inclusion of the three test components in one unit. The built in calibration checks on both instruments were found to be a most convenient adjunct, well worth their small additional cost in materials and labor.

Total cost of this monitor, assuming that all parts are bought new at current net prices, is in the neighborhood of $100.00. Time needed for completion is about six evenings for a worker of average speed who has an electric drill available. Maintenance cost (first year) is zero, but thereafter should consist only of infrequent tube replacements. Calibration drift on both meters, after six months of use, was less than one per cent. After one year of operation, the frequency meter was off one cycle on the 0–100-cps range; and the wattmeter needed a barely discernible retouching to bring it "right on" again. Æ