TESTING—THE GUIDE TO

Products must be tested all along the line—from purchase as raw materials, throughout assembly, to the shipping platform

ACCURATE and sensitive measuring equipment of one sort or another controls the design, engineering and manufacture of every electronic product. From the research laboratory to the production test-bench each component part receives not only its share of individual tests but must be checked again and again as the assembly grows until the final product is ready for shipment—and then again it is tested.

Electronic products—vacuum-tubes and phototubes, radio receivers and transmitters, sound picture and public address amplifiers, are products of considerable complexity in construction and function. Faults in operation or even in construction are usually not visible; they must be discovered by test-operators who are frequently not conversant with the products under test or with the machinery by which that test is made. Rarely do these operators understand what is actually happening. Furthermore the components and completed units must be tested under the high pressure of quantity production; for many electronic products are built in a short season of highly concentrated activity.

Expenditures for instruments

Though the importance of physical research is penetrating every industry, electronics by its very birthplace, the physical laboratory, owes its existence and future to research of fundamental character. Realization of this fact may be one reason for the vast expenditures for costly, complicated, and extraordinarily sensitive testing and measuring equipment that annually finds its way into the laboratory and shops of electronic manufacturers.

The "flow sheet" of design and production tests, on the opposite page, may give some idea of the complex nature of the testing function. Raw materials must be examined for chemical, mechanical and electrical characteristics; components made from these raw materials must be tested to see if they fall within mechanical and electrical limits; these components are assembled into larger units and again testing must reject those whose parts do not fit together properly.

Some of these component parts must all be tested; others are sampled, many of them are tested and sorted. But somewhere along the production line of every unit is a test position which guards against defects which cause loss of time, equipment and money.

Equipment that formerly was sold to and used by only "high brow" scientists now finds its way in increasing quantities representing investments of hundreds of thousands of dollars into the factories of the electronics manufacturers. Standard laboratory apparatus—such as the Wheatstone bridge—is revamped for production testing; complicated instruments are simplified, made more rugged, and are dispersed widely, to become an industry within the electronics industry, that of safeguarding the design and manufacture of radio, audio and industrial applications of vacuum tubes and photocells.

INSTRUMENTS AND APPARATUS FOR TESTING

Antennae measuring equipment

Attenuators

Bridges
- Capacitance
- Conductivity
- Inductance
- Wheatstone
- Low-tension
- Limit bridges, etc.

Coil testers

Condensers
- Precision unit
- Single mica
- Air condensers
- Variable plate, etc.

Gain sets

Galvanometers
- Reflecting type
- Pointer type
- High frequency
- Thermo-ammeter, etc.

Harmonic analyzers

Insulation testers
- Meggers
- High voltage, etc.

Laboratory standards
- Resistance
- Capacity
- Inductance

Mechanical and optical
- Balances
- Gauges
- Micrometers
- Photometers
- Microscopes

Meters
- Acoustimeters
- Ammeters
- Standard voltmeters
- Vacuum tube voltmeters
- Ohmmeters
- Watt-meters
- Frequency meters
- Cross talk meters
- Circuit test
- Flux measuring

Oscillographs

Oscillators
- Tuning fork oscillators
- Fixed frequency oscillators
- Beat frequency oscillators
- Piezo electric oscillators
- Signal generator
- Service-testing

Potentiometers and rheostats

Power level indicators

Pyrometers

Radio set testers
- Portable (service)
- Special production equipment
- Set analyzer

Recorders

Relays

Resistance boxes

Shunts

Special electrical instruments

Stroboscopes

Testing machines (mechanical)

Thermocouples

Thermometers

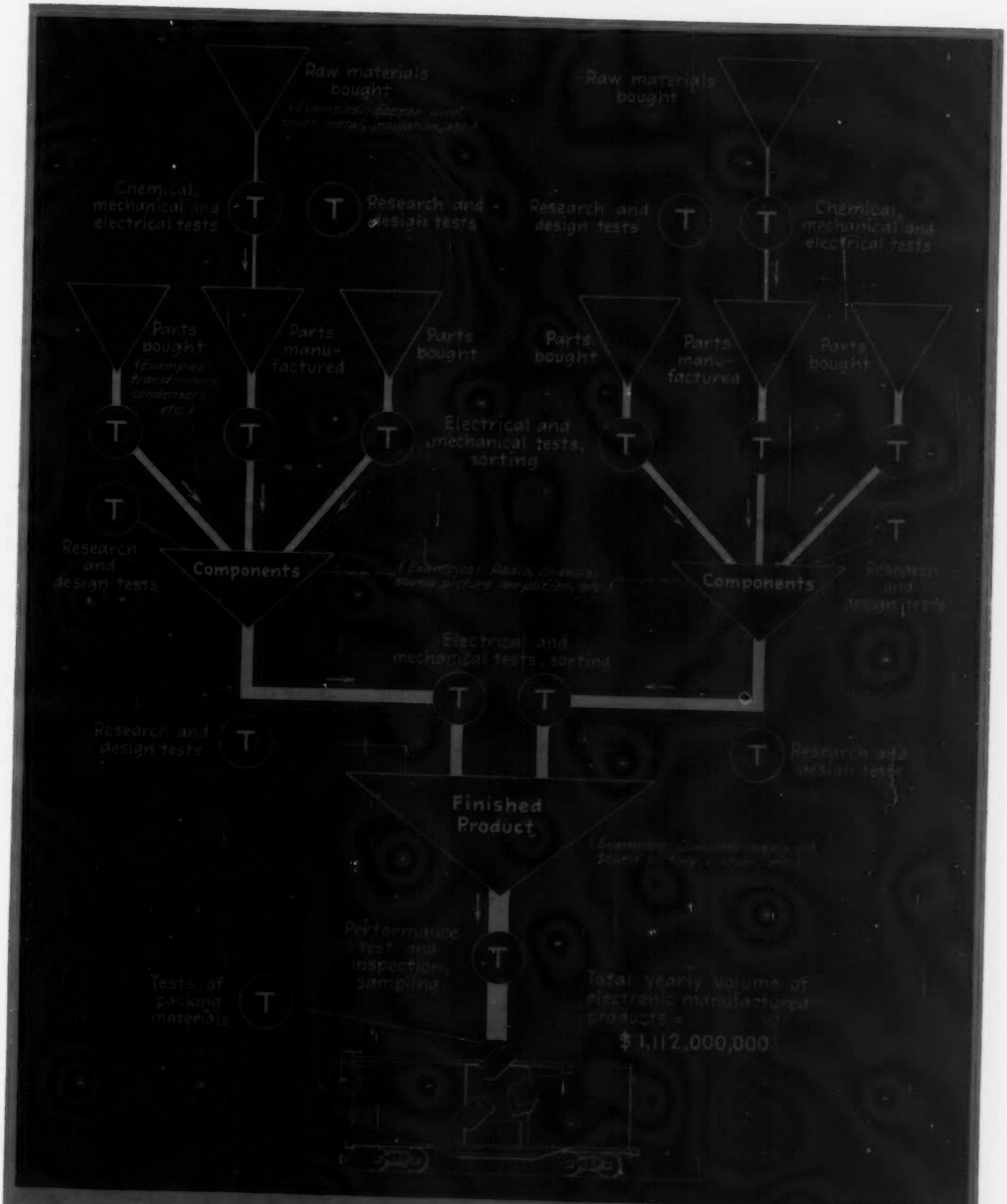
Transformer testers

Tube testers
- Portable (service)
- Special tube production test equipment

Tuning forks

Vacuum gauges

BETTER PRODUCTION



Flow sheet of production tests and design tests
in the electronic manufacturing industries

Production testing of

Present day radio receivers

By GEORGE G. THOMAS

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RADIO receiver design has taken rapid strides during the past five years. Compared with the receiver of five years ago, the average present day receiver has performance characteristics that are unquestionably improved. It operates directly from the power supply line and without the presence of annoying hum. Its tuning operation consists of turning one single knob, or perhaps is accomplished from some point remote from the receiver by means of insignificant looking push-buttons. It is commonplace today that the levels of volume be automatically controlled and that means be provided for easy adjustment of the tone color. The average receiver of today represents quantity production, yet it is built to meet the requirements of critical users and to sell for a price that would have been astonishing five years ago.

Present day sales requirements demand that the performance of the receivers produced be uniform and up to fixed standards. Production methods ask that, in maintaining the quality of the product, as little as possible be sacrificed in production speed, that costs be kept low, and that no factors be allowed to interfere with the smooth rolling of the production line. This means that there is no place for "hay-wire" in the testing equipment. Reliability and accuracy are prime requisites, although speed and simplicity of operation must not be sacrificed. The test equipment cannot be too costly as compared with the cost of the goods being produced, and it must permit of easy maintenance. Elimination of the "human element" where this can be done, is essential. Sufficient tests must be had upon the product in its various stages to prevent defective parts or sets accumulating at any point in the production line, but care must be taken to include no unnecessary tests. These requirements must be and are met by present day testing methods and equipment. A visit to a modern radio factory will show that the testing of the receiver has really kept step with the receiver design.

A summary of the production tests made on a present day superheterodyne receiver would not give a complete picture of the tests involved in producing the receiver, for, raw materials and small miscellaneous parts which are purchased from outside manufacturers are given thorough mechanical inspections upon their entry into the plant. The quality of such materials and parts is further checked in laboratories having the up-to-date equipment needed to determine the conformity of the materials and parts to their specifications as regards chemical, physical and electrical properties.

Testing of component parts

In general, tests on component parts must be fast, accurate, and ruggedly simple. These points are borne in mind in the design of equipment to perform the tests which are outlined above for component parts.

The Wheatstone bridge circuit is easily adapted to production testing of resistances. In this application, sensitive galvanometers protected from overloads by quick acting relays indicate whether or not the resistance being measured is within limits.

Visual oscillographs lend themselves readily to the accurate and quick testing of chokes and small capacitors. The unit under test forms part of an oscillating circuit and the capacitance or inductance of the unit is suitably translated to the large screen of the visual oscillograph, the value of capacitance or inductance being indicated by the position of a line of light on the screen.

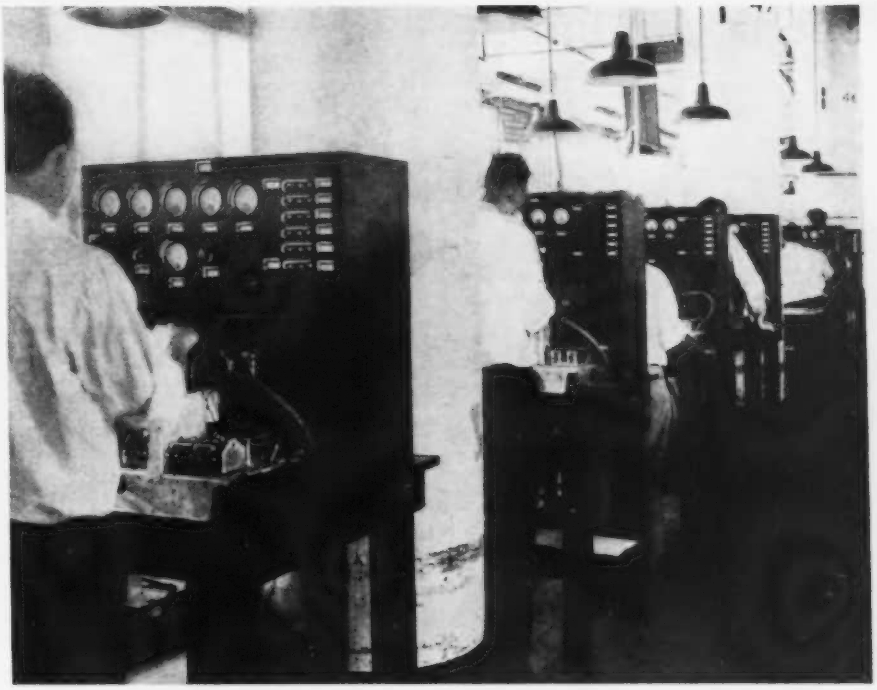
Visual oscillographs have also proved to be of unestimable value in the testing of intermediate frequency transformers. An input whose frequency varies for a short range on either side of the frequency, prescribed for the intermediate frequency amplifications, is fed to the transformer under test. The output of the transformer is reflected in the form of a visible resonance curve on the screen of the oscillograph. By this means, the primary and secondary circuits of the intermediate frequency transformer can be accurately adjusted to give a curve of the desired shape and amplitude.

The extreme accuracy required for the alignment of tuning capacitors and the adjustment of radio frequency transformer secondaries is best obtained by the beat frequency method. This system enables adjustment of capacitance or inductance to be made with an accuracy of 0.1 per cent or better. In this method of test, the coil or capacitor is inserted in the circuit of a radio frequency oscillator whose frequency is adjusted by means of a calibrated variable capacitor to "zero beat" a fixed frequency oscillator. The fixed frequency oscillator is controlled by a quartz crystal and indication of the "zero beat" is had either by aural or visual means.

Here radio frequency circuits are adjusted and sensitivity is measured

High voltage or "hipot" tests to determine the strength of dielectrics and insulating materials as used on different component parts are of great importance in order that no voltage breakdowns occur on the receiver during its normal life. Such tests are usually conducted with the part to be tested inserted in a jig which makes the necessary electrical connections and also protects the test operator from possible contact with points of high potential. The high voltage is automatically disconnected from the test fixture when the part is removed from the jig, but as an additional safeguard, it is standard practice that the high voltage only be applied when the test operator depresses two separated push-buttons, requiring the use of both the operator's hands.

Automatic tests have found application in the testing of some component parts. The more or less laborious tests required for power transformers are made on an equipment that automatically sorts out the defective units. Automatic "hipot," capacitance, and resistance tests on the less complicated component parts have been developed.



Test positions for determining continuity and resistance of circuits in receivers

When the receiver chassis has been completely assembled by the factory, it can be assumed that the parts making up the chassis have the correct electrical and mechanical constants. The testing work, however, is far from being complete, and with the receiver in chassis form, such tests as circuit continuity, check on the alignment of the intermediate frequency amplifier, adjustment of the radio frequency and oscillator circuits, sensitivity, and general performance, must be made.

Due to the extreme sensitivity of the present day superheterodyne, elaborately screened rooms are required for the tests on the intermediate frequency amplifier and overall tests on the receiver chassis. Such screened rooms are built using solid copper for the floors and for the lower part of the side walls with copper screening for the upper side walls and the ceiling to give needed light and ventilation. Power lines entering the screened room must include properly designed electrical filters to prevent radio frequency signals or disturbances from entering the room over such lines.

Continuity tests

Checking the continuity of the receiver has been simplified as far as possible. In conducting this test, it is necesary for the operator to insert "dummy" tubes in the sockets of the chassis and make observations on certain meters when several different switches are depressed. The continuity of the circuits and the correctness of voltages at different points is indicated by single limit lines on the meters. Conveyor systems then carry the chassis into the shielded room for test on the intermediate frequency amplifier alignment and the overall test on the chassis. The intermediate frequency amplifier alignment is checked on a visual oscillograph in a manner similar to that described for the individual intermediate frequency transformer. It is necessary that the curve shown on the oscillograph screen be of prescribed shape and amplitude. Having passed the intermediate frequency alignment test, the receiver is carried by the belt conveyor to the chassis radio frequency test positions, where the trimmer condensers on the radio frequency stages and oscillator are adjusted so that maximum sensitivity is had from the receiver. The alignment of the trimmer condensers must also be such that the frequency calibration of the receiver is within specified limits. Tests for sensitivity and the frequency calibration are made using signals of known frequency and intensity supplied from master signal generators located in a shielded cage external to the screened room used for testing the receiver. Signals from this master signal generator are fed into the test room through well-shielded radio frequency transmission lines. The percentage modulation and radio frequency voltage input to the transmission lines are accurately maintained at the signal generator. Calibrated attenuators at each test position in the shielded room enable the test operator to select signals of the desired frequency and intensity. The output of the receiver is indicated either on a loudspeaker or an output meter calibrated in terms of a standard output power.

After satisfactorily passing the tests in the radio frequency test room, the chassis is sent on to a point where it is assembled in a cabinet with the socket power unit and loudspeaker. It is then given a final check in a shielded test room similar to that used on the chassis test. The final test includes the measurement of sensitivity, the hum voltage across the loudspeaker, a check on the dial calibration, and a listening test where a music modulated signal is picked up by the receiver.

The quality of the receiver as it is ready for shipment is further checked by taking a small percentage of each day's production into laboratories specially equipped for sample checking the performance and operation of receivers. In these laboratories, equipment is available for accurately and quickly measuring all the receiver characteristics, including sensitivity, selectivity and fidelity. Tests made on this basis give valuable engineering data and afford a valuable means for controlling the tests made on the production line.

Special instruments for

Radio receiver production testing

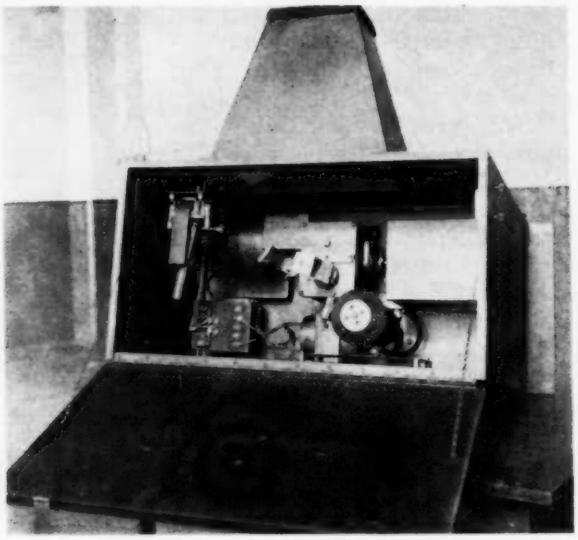
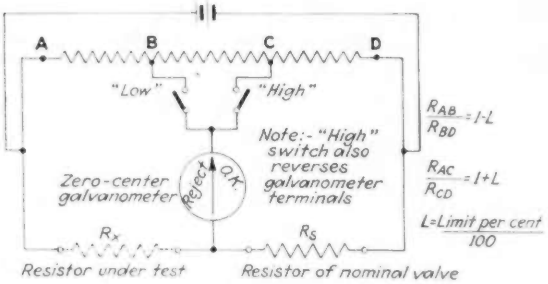


Fig. 2—Visual oscillograph for testing component parts showing the optical system

By RALPH P. GLOVER

THE era of mass production in radio receivers has brought with it many new problems for the test engineer. The better performance of receivers, which is the natural result of progress in the art and the demand for a finer product by the consumer, calls for a higher degree of manufacturing precision and more exhaustive test procedures than were required only a few years ago. In many cases it has become necessary to make tests in the factory which formerly were considered to be the special province of the laboratory. In addition, to fit in with modern production methods, apparatus must be sufficiently simple in operation to permit rapid handling by unskilled or semi-skilled employees.



Magnitude of R_x	Galvanometer Deflection "High" (Reversed)	"Low"	
Less than lower limit $\frac{R_x}{R_s} < (1-L)$	OK	Reject	Reject
Equal to lower limit $\frac{R_x}{R_s} = (1-L)$	OK	Zero	Pass
Between limits $(1-L) < \frac{R_x}{R_s} < (1+L)$	OK	OK	Pass
Equal to upper limit $\frac{R_x}{R_s} = (1+L)$	Zero	OK	Pass
Greater than upper limit $\frac{R_x}{R_s} > (1+L)$	Reject	OK	Reject

Fig. 1—Diagram of a "limits" bridge—an adaptation of the Wheatstone bridge

These demands have been met by numerous special instruments, designed particularly for the process involved. Many of them are simply familiar pieces of laboratory equipment, redesigned and adapted for operation over a limited range with the minimum expenditure of time and energy by the operator; others involve new practices and have furnished the industry with new and important tools.

Adaptation of the Wheatstone bridge

Bridge methods have been used for all sorts of precision laboratory measurements ever since Sir Charles Wheatstone conceived the principle early in the nineteenth century. However, in its usual general-purpose form, the bridge is ill suited for production use. More or less skill is required in operation and time-consuming adjustments are necessary to obtain a balance.

The *limit bridge* is a special application of a bridge network and is used extensively for production testing of resistors. It indicates whether or not the unit under test falls within the permissible variations from the nominal or specified value. Fig. 1 represents a basic limit bridge circuit. One side of the bridge is tapped to give "Low" and "High" ratios corresponding to the lower and upper limits as shown. A zero-center galvanometer is used as a detector. Switching from "Low" to "High" may be conveniently accomplished by the use of push-button switches placed side by side so that they may be operated in succession by adjacent fingers. The "High" switch also reverses the galvanometer terminals when it is depressed. This arrangement is not shown for sake of simplicity. A resistor of the nominal value is used as a standard. Inspection of the figure will show that all deflections of the galvanometer are in the same direction, say to the right, provided the resistors are within the specified limits. The right side of the scale can hence be marked "OK" and the left "REJECT." When the "High" button is depressed, the galvanometer deflects "OK" provided the unit is not above the upper limit. Similarly, the galvanometer points to "OK" when the low button is depressed if the unit is not below the lower limit. Bridge of this type have also been devised for measuring small condensers and are commercially available as well for tube measurements.

Condenser test equipment

The principle that the alternating current through a condenser is proportional to the capacity for constant impressed voltage and frequency, is made use of in the construction of direct-reading capacity meters or "microfaradmeters" as they are sometimes known. They are well suited for work which does not require extreme accuracy, a fact which qualifies them for use in testing filter, by-pass and other large condensers used in radio receivers. A particular advantage of this type of device is that it is readily combined with other panel-type instruments to form a complete unit for condenser testing. High voltage, capacity and leakage tests can thus be made at the same test position without expensive rehandling.

Visual test apparatus

An ingenious combination of laboratory methods of testing receivers and well-known principles of oscillography, has recently been developed by engineers of the RCA Victor Company. The particular apparatus referred to projects the selectivity curve of an intermediate amplifier of a superheterodyne receiver on a translucent screen before the operator and the results of the aligning process are at all times visible. This affords an entirely new degree of control over receiver characteristics as they pass through the factory. Formerly it was necessary to rely entirely on sensitivity observations for an indication of correct alignment; the new apparatus permits accurate inspection of the entire intermediate gain-frequency curve. Quite apart from the commercial aspects of the development, universities and other educational institutions will no doubt welcome the device for lecture-room demonstration purposes.

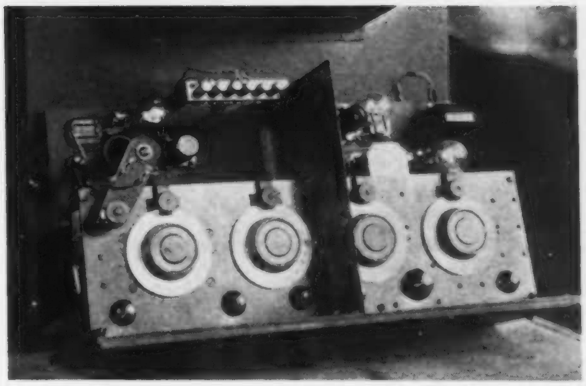


Fig. 3—Oscillator and detector of oscillograph for production testing

Fig. 4—Bridge circuit for vacuum tube measurements

Production testing of audio amplifiers

Manufacturers of radio receivers and audio amplifiers usually rely upon careful inspection of the individual audio components and aural tests in order to secure the desired characteristics. While in a majority of cases satisfactory results are obtained in this manner, a further check on the overall performance of the audio amplifier may be desired. Equipment which makes possible the rapid determination of the gain-frequency and overload characteristics of amplifiers at a number of points in the audio range, has been recently described.[1] The apparatus is basically that used for laboratory gain measurements, ingeniously adapted for high-speed inspection work. An electron-tube oscillator, operating at a number of discrete audio frequencies which are in turn selected by the operator, furnishes a constant voltage to the amplifier under test through calibrated attenuation networks. Comparison of input and output is readily obtained through the use of a simple a.c. operated electron-tube voltmeter. The gain is then given directly by the reading of a pointer on the shaft which controls the attenuator. Obviously no new principles are involved, but the assemblage of apparatus described is a noteworthy adaptation of precision laboratory apparatus for high-speed production service.

Loud speaker testing

For some time, development laboratories have employed more or less delicate apparatus for determinations of the sound pressure-frequency characteristics of loud speakers. Until recently, however, this has been a matter for the skilled acoustic technician. Much time and painstaking care were necessary to secure significant results. Several semi-automatic methods are now available for securing data on acoustic performance.[2] We are informed that at least one radio manufacturer[3] is developing such apparatus for use on the production line. The loudspeaker is driven by a variable-frequency oscillator and the output is picked up through a condenser microphone and amplifier. Several varieties of recorders are in use, ranging from a light beam to curve-tracing mechanisms geared to the oscillator frequency control and an attenuator in the pick up circuit. Further simplifications may be anticipated.

It is significant that in only a few instances have production testing facilities reached the fully automatic stage. The electron tube and photocell undoubtedly have an important part to play in future developments.

[1]Thiessen, The Accurate Testing of Audio Amplifiers in Production, *Proc. IRE.*, February, 1930; p. 231.

[2]For instance: Barnes, Measurement of the Performance of Loud Speakers, *Experimental Wireless*, June, 1930; p. 301.

[3]Graham & Olney, Engineering Control of Radio Receiver Production, *Proc. IRE.*, August, 1930; p. 1351.

Testing of sound-picture channels

By G. F. HUTCHINS

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SOME of the important tests and instruments necessary to maintain a recording channel in perfect condition are outlined in the accompanying article.

THE problems of maintenance and repair of sound equipment in motion picture studios are somewhat different than those encountered in allied fields. In the radio business, for instance, repairs and tests are quite often delayed until trouble is encountered, whereas with sound recording equipment, the cost of continuous check and maintenance is quite small when compared with the financial outlay on a sound production. In picture production repairs to sound equipment usually consists of replacements of complete units when trouble is encountered. The actual test and repair of the faulty unit is then much the same as in the case of radio equipment, and may be carried out at leisure, so to speak, while a spare equipment is used to carry on production. The problem unique to the studio is then to have at all times a complete knowledge of the conditions of each channel available, and an assurance of satisfactory performance by all channels in production, and others which are expected to insure continuous operation. In meeting this problem, routine tests are made on the equipment, usually daily, and sometimes oftener.

A sound recording channel, when the record is made on film, consists essentially of a microphone and its associated amplifier, a mixer and amplifier system which may be regarded as a unit for the purpose of this treatment, and the recording machine or "sound camera" which photographs the record of the speech circuit modulations. Maintenance on the latter is commonly placed in the hands of a group of specialists who confine their activities to the recorders alone. The nature of this work depends entirely upon the type of machine used, and to thoroughly discuss the details here would involve a separate treatment of each of the several types of recorder in use. The speech channels, on the other hand, are in general all quite similar, and the common practices in vogue for making measurements on them are applicable to all.

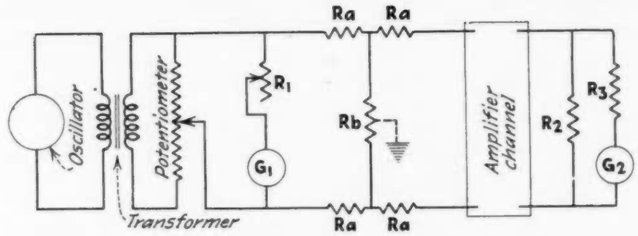

Fig. 1—Diagram of typical measuring circuit applicable to mixing and amplifying equipment found in modern studio installations

A commercial routine test on a sound channel should consist of a continuity test, a check of the condition and operation of each component part which might give trouble, frequency characteristics under all operating conditions, and a check of overall gain.

In checking and testing individual parts, a resistance bridge is indispensable. Trouble may be quickly located with a circuit continuity tester, many such devices being obtainable with approximate resistance readings on the scale, but an accurate wheatstone bridge is necessary for obtaining assurance of proper functioning of the various circuits in an amplifier used in this work. An extremely valuable device is one which allows each tube to be operated in a remote circuit containing complete metering equipment for the observation of all tube currents and voltages under actual operating conditions. Such "tube testers" are really more than the name implies, for they furnish an excellent check on the complete circuit as well as on the tube itself.

High quality instruments essential

Since the quality required in recording sound for motion pictures is of necessity much higher than in other branches of the sound industry, measuring apparatus employed in this work should be of very high quality. The use of mediocre or inferior measuring equipment on apparatus which is used in the making of productions costing many times the value of the equipment itself is obviously false economy.

Figure 1 shows a scheme of measurement applicable to most types of mixing and amplifying equipment found in modern studio installations. The section denoted as "amplifier channel" may consist of one amplifier, an amplifier and mixer, or almost any combination having an input impedance in the neighborhood of 500 ohms, and an output impedance of 500 ohms or less. This includes most mixer and amplifier combinations commonly in use. The oscillator should be chosen with the greatest care. Whether it be of the single oscillator or the beat frequency type, its harmonic content should be a minimum, and in no case greater than 4 per cent of the fundamental within the band of 50 to 10,000 cycles. Its voltage output need not be perfectly constant with changing frequency, but the required power should be avail-

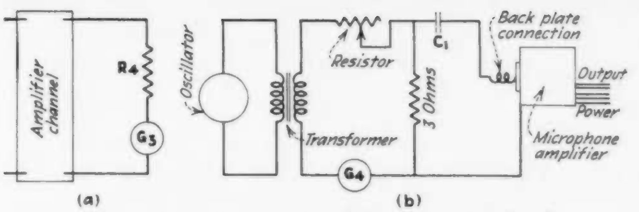

Fig. 2 (a)—Output circuit for measuring load of low impedance using thermo-coupled milliameter

(b)—Circuit for supplying constant input to microphone amplifier making it part of channel under measurement

able at all frequencies. From zero to plus ten decibels of power output are usually desirable with the scheme in question. Several oscillators are commercially available which meet these requirements. If the oscillator output impedance be too high for operation on the input line, a step-down transformer may be used to reduce the output impedance to something not exceeding the line value. In case the oscillator is not provided with a convenient volume control, or if further adjustment is desired, a potentiometer is introduced here to completely control the voltage input to the line. A slide wire or comparable type of potentiometer is satisfactory for this purpose, and may be in the order of 3,000 ohms for feeding a 500-ohm line.

From this point on the line is padded to exactly the impedance of the amplifier or mixer input circuit, and the input measurement should therefore be made at this point. The line voltage is measured with either a vacuum tube type of voltmeter, or a thermo-coupled device. The latter is usually preferable for frequency characteristic measurements. If a thermo-coupled milliammeter is used at G_1, as is good practice, a series resistor R_1 is used to raise the impedance of the meter circuit sufficiently to maintain good efficiency from the oscillator. The value of R_1 may be of such value as to make the total meter circuit resistance a round number to simplify calculation. In order to meter this circuit at low impedance, a fairly high signal level is required, and a pad attenuator must then be introduced in order to drop the line level exactly a known amount and at the same time maintain a constant line impedance. Such attenuators are available on the market, and are rapidly adjustable, usually in steps of one-half or one decibel. A total attenuation of about 60 decibels should be available. From the current and impedance relations existing, general expressions may be derived for obtaining the values of R_a and R_b at known attenuations with any given line impedance. These expressions are:

$$R_a = \frac{Z}{2}\left(\frac{K-1}{K+1}\right), \text{ and } R_b = 2Z\left(\frac{K}{K^2-1}\right)$$

where Z is the line impedance, and $K = \text{antilog } N/20$, N being the attenuation in decibels.

In case the input circuit of the amplifier is ungrounded, it is well to ground the center of R_b so as to stabilize the line, but if the amplifier input circuit is already grounded at any point no ground should be used on the attenuator, as this might cause the input circuit to carry part of the filament current to the amplifier, in case the filament circuit were also grounded, as it is usually. If the output impedance is of the order of 500 ohms, an output circuit consisting of R_2, R_3 and a thermo milliammeter G_2 form a good combination as shown in Fig. 1, for R_2 and R_3 may be so balanced as to make their parallel circuit, with the meter, equal to 500 ohms. In the case of most recorders, the load circuit is of very low impedance, usually about 2 to 10 ohms, and the output transformer may be designed to work directly into a load of this value. In such case the output circuit of Fig. 2(a) is sufficient with G_3 a thermo-coupled milliammeter of about one ampere capacity and a series resistor R_4 of the value of the load impedance minus the meter resistance.

Calculations for meter settings

As an example, suppose we have an amplifier and mixer with both input and output impedances of 500 ohms. If this channel is designed to operate a recording machine requiring a power level of +10 decibels, it will be desirable to hold the output level at this value while making characteristic and gain measurements, if the

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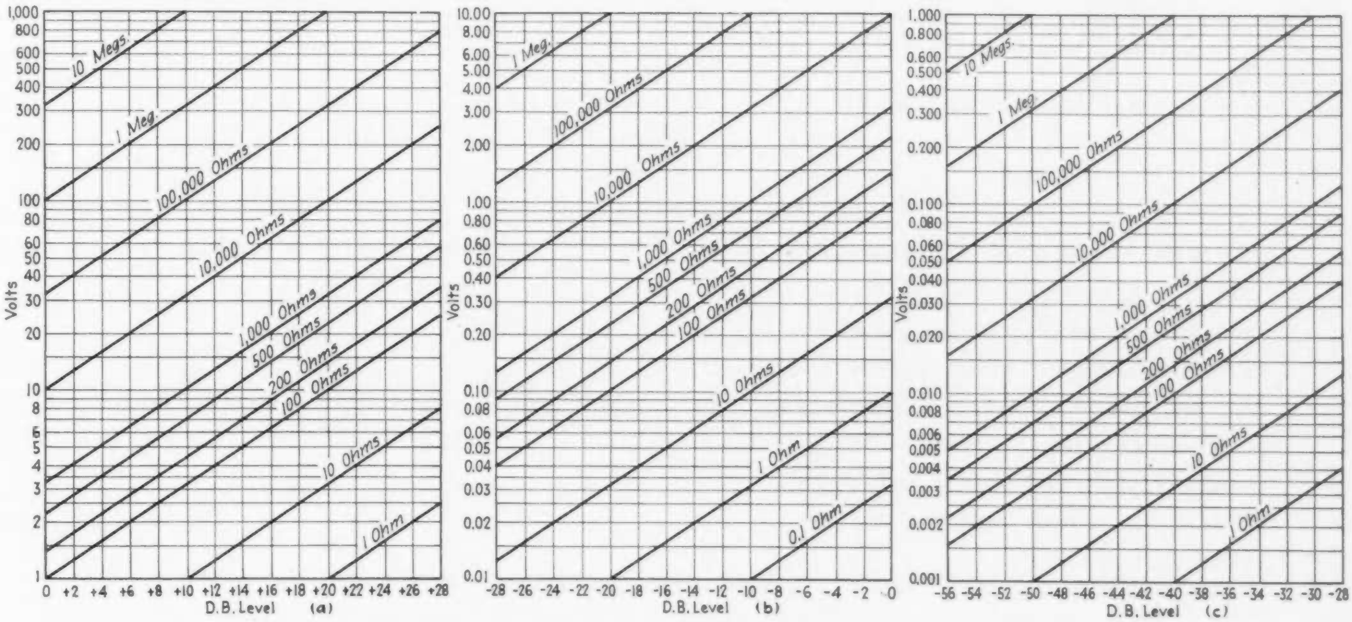

Fig. 3—These curves, representing various impedances, taking zero level at 10 milliwatts, show the correct line voltage to give desired level

By-pass condenser production test equipment

By FRANK W. STELLWAGON

Test Engineer, A. H. Grebe & Co., Inc.

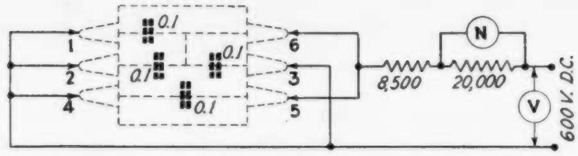

Fig. 1—Circuit for the high voltage test

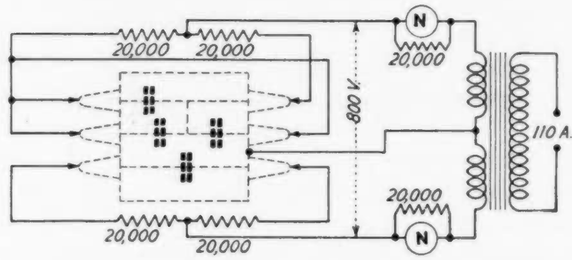

Fig. 2—Circuit for (a) discharging condensers, (b) testing at 400 volts for solder lugs poorly insulated from container, and (c) testing at 800 volts between individual lugs for insulation

THE by-pass condenser test apparatus shown in the photograph is capable of completely testing over 500 by-pass condenser units per hour. The tests include a ten-second test at 200 per cent of rated d.c. voltage, discharging of the charged condensers, testing the insulation between the condenser terminals and the container, and checking the capacity of the four condenser sections.

The test apparatus consists essentially in three individual test circuits combined so as to permit making the above tests successively at one handling of the condenser unit.

A rotating wheel is used having on it six test mountings for holding the condenser units. Each test mounting is connected to a brush carriage holding seven brushes. Seven brushes are necessary to contact with the six solder lugs and the container of the condenser unit. The brushes rub on a seven-ring track, each ring being divided into six 60 degree segments which are insulated from one another.

Referring to the photograph, the track segment opposite position *A* is wired to the circuit of Fig. 1. Likewise the track segment of position *B* is wired to the circuit of Fig. 1. Both positions *A* and *B* apply a 600-volt d.c. test for about five seconds. The breakdown of a condenser is indicated by the glowing of either of the neon lamps *A* or *B*, depending on which position the breakdown occurs.

The track segment opposite position *C* connects to the circuit of Fig. 2. The condensers which were charged in position *B* are now discharged through resistors. Poor insulation between the container and the six solder lugs is detected by means of a 400-volt test; the insulation between the lugs 1, 2, 3, 6 to lugs 4, 5 is checked at 800 volts. The glowing of the neon lamp *C* indicate an insulation failure.

The capacity test

The track segment opposite the capacity position connects to the circuit of Fig. 3. In this test a constant voltage of 220 volts a.c. is held across the condensers and the capacitative current indicated on the four meters *C*-1, *C*-2, *C*-3 and *C*-4. The Hi-Lo switch connects in standard capacitances having the acceptable minimum and maximum capacitance values which can be switched in each of the four meter circuits in turn to obtain the

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AMONG a number of interesting and time-saving pieces of production testing equipment in use in the Grebe factory is an ingenious device for testing by-pass—or power condensers. By turning a handle each of several condenser units is successively brought into a new test position by the operator.

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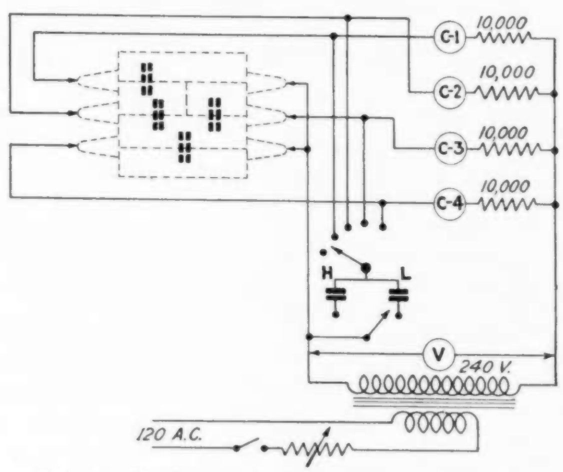


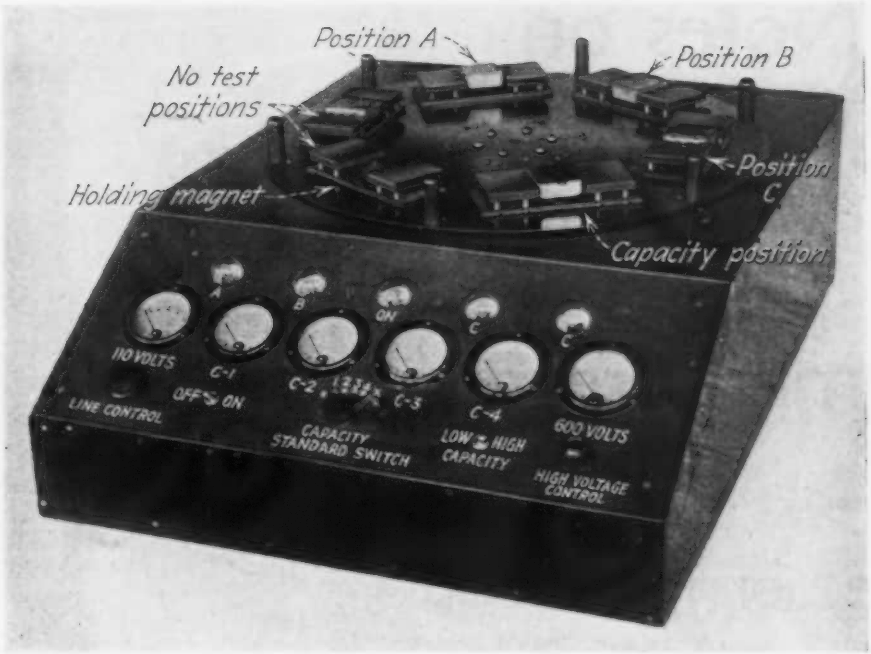
Fig. 3—Condensers in this circuit are tested for capacity

meter limits for acceptance of the condenser units.

The remaining 120 degrees on the test track is the no-test position where the brushes contact with no circuits. It is over this range that the operator removes tested condenser units and replaces them with untested ones.

Fig. 4 shows the wiring diagram of the seven-ring track to the three circuits discussed above. The power supply for the apparatus is shown in Fig. 5.

A feature of the apparatus is the holding magnets used on each test mounting. The iron containers of the condenser units are held firmly in position by the magnets assuring good contact between the test mounting contacts and the solder lugs of the condenser unit. The six holding magnets are connected in a series on the test wheel and power is supplied through a brush wiping on a ring connected to a 280 rectifier.



Photograph of the completed test apparatus. The operator pulls the condenser into new test positions by means of the handles

The power pack test apparatus embodies the same fundamental principles of operation applied to the by-pass condenser test apparatus discussed above. It tests completely a five-condenser section power pack at the rate of 500 packs per hour. The tests include a ten-second test at 200 per cent of rated d.c. voltage, discharging the charged condensers, testing the insulation between the condenser terminals and the container, and checking the five condenser sections for capacity.

The condenser packs are placed on the wheel with the solder lugs projecting through the holes on the test wheel against contact springs. Magnets firmly hold the iron container of the power pack to the test board.

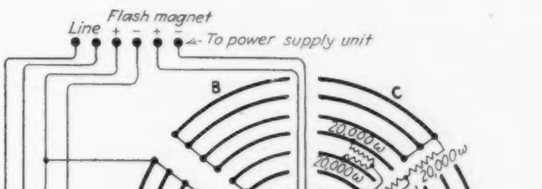


Fig. 4—Wiring diagram of the by-pass condenser test equipment

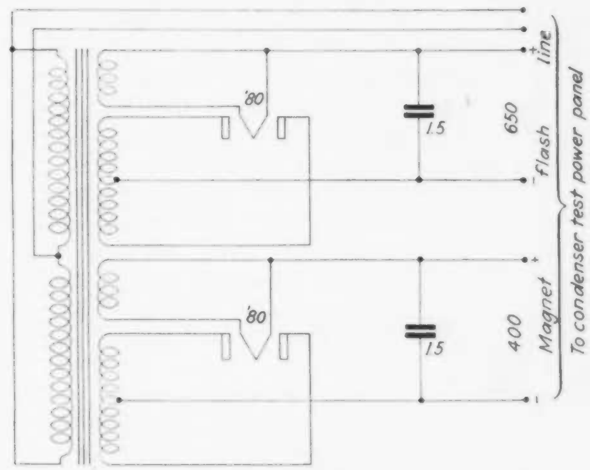


Fig. 5—Power supply circuit for the 0.1 mfd. by-pass condenser test

Glowing of neon lamps indicate that the condenser pack has one or more condenser sections which have failed on the 200 per cent rated voltage test, or that a solder lug is poorly insulated from the container. In the "Capacity" position, the meters indicate the capacity current of the respective condensers making up the condenser pack.

A standard capacity switch connects in the correct high and low values of capacity in the five respective meter circuits so that acceptance limits for each of the five condensers in the condenser pack may be easily determined at any time by the operator.