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ELECTRON

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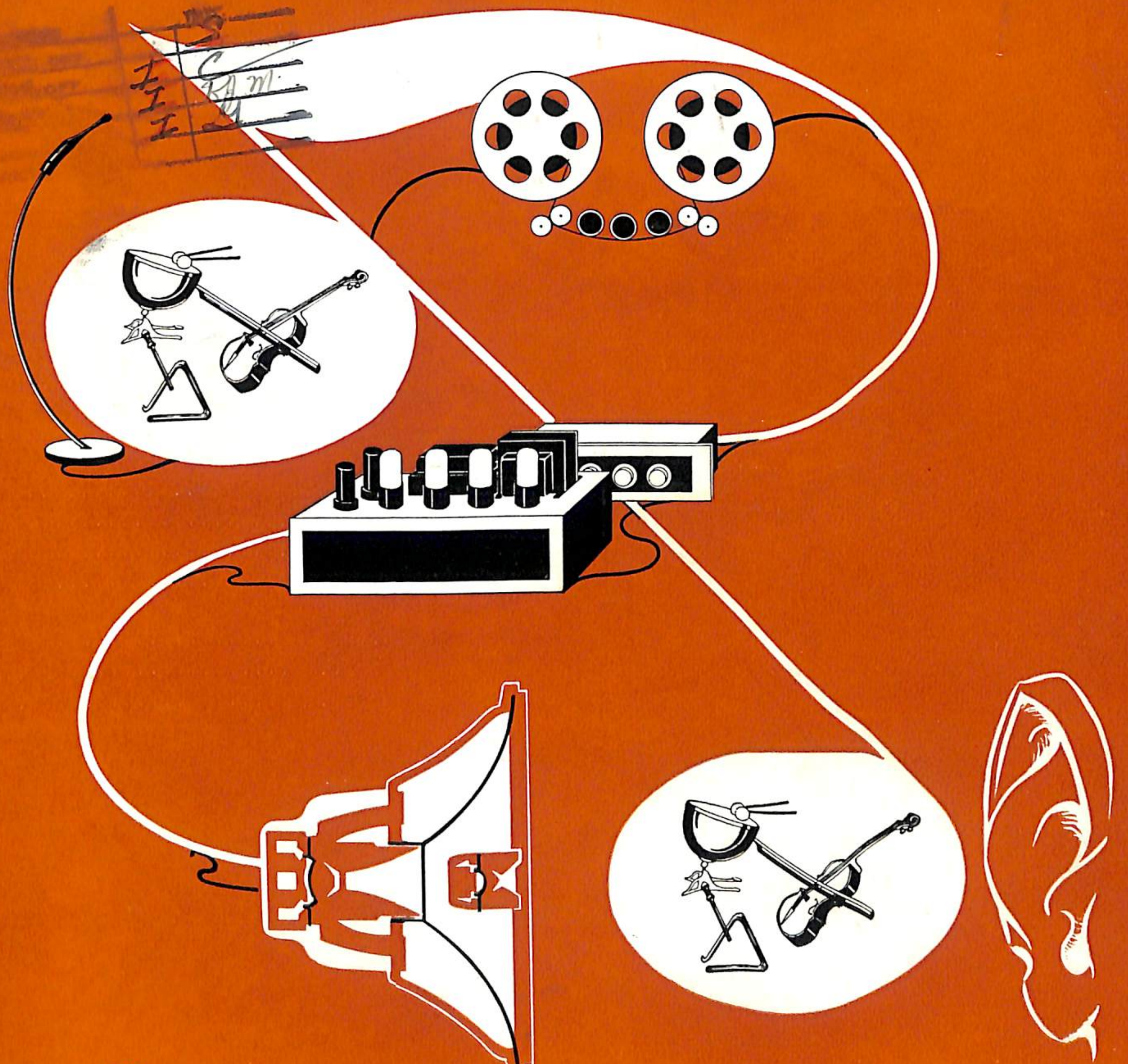

RESTRICTED

IN THIS ISSUE

RESPONSE OF AUDIO AMPLIFIERS

RESTRICTED

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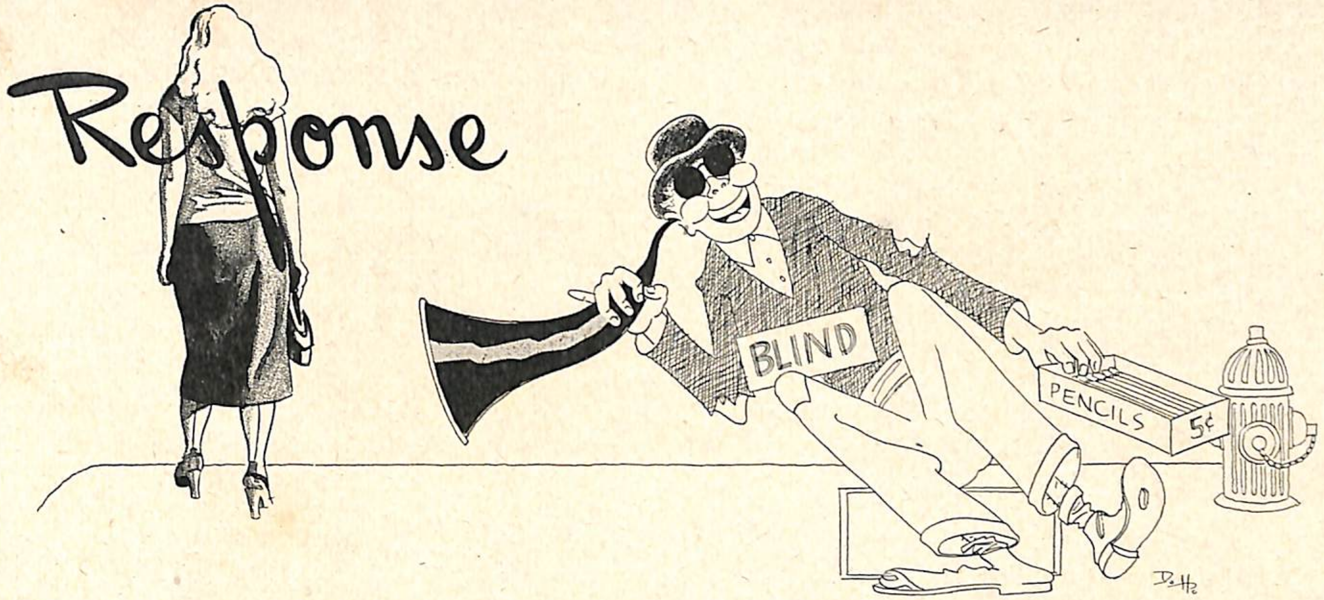

Response of AUDIO AMPLIFIERS

by

Cdr. Charles W. Harrison, Jr., USN
U. S. Naval Research Laboratory

Introduction

Most Electronics Technicians have a profound interest in audio engineering—the design, construction and use of electronic equipment for the reproduction of speech and music. This paper is addressed to the Electronics Technician whose vocation as well as avocation is Electronics. It may be regarded as a sequel to the articles "High Fidelity Sound Systems" and "Dual Loudspeakers, Pickups, Equalizers and Amplifiers" which appeared in the December 1948 and May 1949 issues of BuShips Electron Magazine, respectively. The writer's intention is to present a brief, non-mathematical survey of the literature[1] in the field of audio amplifier response and distortion, followed by a discussion of some topics in audio engineering that are only generally related, such as output transformer measurements, response of magnetic reproducers, and recommended circuit modifications to the Western Electric amplifiers described in the earlier articles. Of interest is the presentation of a resistance-capacitor filter for use as a cross-over network in a dual channel amplifier system.

Frequency and Phase Response—Manifestations of the Same Phenomenon

If the frequency response characteristic of an amplifier is known, it is possible to compute the associated phase shift provided the circuit meets the definition of a minimum phase shift network. A minimum phase shift network is defined as one that does not contain essentially dissipationless phase shifting devices. A network containing a transmission line section is a good example. It is well known that a transmission line section may shift the phase of a voltage or current without the introduction of appreciable attenuation. Another example of a circuit which does not meet the definition of a minimum phase shift network is one that is operated at such high frequencies that the tubes and network elements fail to obey lumped circuit analysis. Here the phenomena of transit time in tubes and retarded action at a distance in circuits give rise to shifts in the phase of voltages and currents independent of their attenuation.

In general it is easy to recognize circuits that do not meet the definition of minimum phase shift networks. The audio engineer may safely assume that the circuits he is interested in are of the minimum phase shift variety, removing all chance of ambiguity.

There is a certain irreducible minimum phase shift associated with any frequency discriminatory circuit. Since interest here centers in minimum phase shift networks, it is clear that if the frequency response characteristic of an amplifier or equalizer (whether active or passive) is fixed, its phase response characteristic is unique and calculable. Resorting to actual phase measurements in the laboratory is unnecessary.

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[1] When the original author's statements are particularly appropriate, they are reproduced in this article with little or no change in wordage.

To reiterate—changing the frequency response of an amplifier changes its phase response in a perfectly predictable and calculable manner. It is very important to understand this statement, for it will be shown in a subsequent section that frequency and phase response uniquely determine transient response, i.e., response to square waves. Thus determination of the phase response of an amplifier may be regarded as an intermediate step in the solution of the following problem: Given the frequency response characteristic of the amplifier, compute its transient response.

Transient Analysis of Audio Amplifiers—Indicial and Square Wave Response

It is a well known fact that a passive circuit consisting of linear impedance elements, as for example, a filter, may possess non-uniform frequency and phase response characteristics. But such circuits may be analyzed for transient response utilizing the Laplace Transform or the methods of the Heaviside Calculus. An amplifier may be analyzed for transient response using these methods provided it does not generate frequencies not originally present in the input signal. This is equivalent to saying that the amplifier transfer characteristic must be linear. Harmonic distortion generated by the amplifier must be zero. As will be shown later, a necessary consequence of this statement is that intermodulation distortion is also zero. Now these distortions are small in a high quality amplifier, accordingly it is permissible to apply operational methods to the solution of the transient response problem, if small inaccuracies are permitted.

The indicial response of an amplifier may be defined as the instantaneous voltage developed across the load (preferably a resistor) due to the application of a suddenly applied unit voltage which thereafter remains constant. A voltage of this character could be obtained from a small battery, such as a flash-light cell. The applied voltage might be regarded as a square wave of unit amplitude and infinite period. It can be demonstrated mathematically that the reaction of the amplifier to this suddenly applied voltage determines its reaction to any type of input signal.

All sound transmission, particularly orchestral music may be regarded as a transient problem. The indicial response will depart from the ideal square form, and this departure is a measure of the relative faithfulness of wave form reproduction. Thus the more closely the indicial response approaches the shape of the test signal, the more closely the output of the amplifier will be a copy of the arbitrary speech and music wave fed into the amplifier. It is to be borne in mind that to obtain an absolutely true reproduction of the applied step voltage necessitates a uniform frequency response characteristic from zero to infinite frequency.

The high frequency response of the amplifier determines the shape of the transient, at and for a short time after the application of the step voltage, and good high frequency response results in the reproduction of this sudden change in voltage as a steep and straight line transition without over-shoot. The low frequency response, which is usually controlled by the self-inductance of the primary winding of the output transformer, determines the shape of the transient waveform after a much longer time has elapsed.

The existence of oscillations in the indicial response, or "ringing" as it is termed, is caused almost entirely by the deteriorating amplitude (and consequently phase) characteristic of the amplifier at the high frequency end of the pass band. In a d-c amplifier the frequency response can be made flat from zero to some finite frequency. In an amplifier employing coupling capacitors between stages the frequency response can be made flat only over a limited frequency interval. Since a falling off in frequency response is inevitable at high frequencies, it is of great importance that the curve taper gradually (with no discontinuities) in the interest of minimizing oscillations in the indicial response. Thus the indicial response of an amplifier shows emphatically the importance of a smooth, slowly variant, frequency response characteristic. The importance of proper damping, the need for which is necessitated by transformer resonance, is clearly brought out by the existence of oscillations which are to be avoided or minimized.

It was pointed out earlier that the frequency response characteristic of an amplifier uniquely determines its phase response characteristic. These two responses, taken together, uniquely determine the indicial response. Thus once the overall frequency response of an amplifier (including the equalizer) is determined, its indicial or transient response is fixed. Conversely, if the indicial response of an amplifier is known, it is possible to determine analytically its frequency and phase response. The governing mathematical laws are inexorable.

Often the indicial response of an amplifier closely resembles the mirror image of its frequency response characteristic.

It is customary to determine the transient response of an amplifier by driving it with a square wave generator and observing the wave shape of the voltage developed across the load impedance, making sure to use an oscilloscope capable of good square wave response. Usual practice dictates that measurements be made employing square waves of fundamental frequency corresponding to the low, high and geometrical mean frequency of the normal transmission range. If the desired band width is 30 to 15,000 cycles per second, square waves of period $\frac{1}{30}$, $\frac{1}{671}$ and $\frac{1}{15{,}000}$ second would be used. The test using the square wave of period $\frac{1}{671}$ second is for establishing a reference for measurements.

It has been pointed out that a square wave, due to its harmonic composition, investigates the amplitude and phase characteristic of an amplifier over a wide range of frequencies with but one setting of the test equipment controls. This is true because a square wave consists of a fundamental sine wave and its odd harmonics, which have fixed amplitude and phase relationship. If the transmitted wave is square, the amplifier can be considered to have a flat frequency response for at least 4 octaves above the fundamental frequency of the square wave, and to have zero phase shift, or phase shift proportional to frequency. If the amplifier is critically damped, no oscillations will appear on top (and bottom) of the output voltage wave. The square wave affords an excellent tool for amplifier testing, because slight changes in the frequency-phase characteristic profoundly affect the output wave shape.

The fidelity of the amplifier at high frequencies is shown by the steepness of the wave front, and character of the damped oscillations, if any, when a square wave of high repetition rate is used as the input signal. The amplitude and duration of the oscillations, or ringing are determined by the sharpness of the high frequency cut off, and the frequency of ringing approximates the frequency at which the rate of change of the frequency response characteristic is most rapid. Thus a flat frequency characteristic with sharp high frequency cut off (as might be obtained by using a filter composed of condensers and iron-core reactors), will give results inferior to those obtained with a gradually tapering frequency characteristic from the point of view of good transient response. Good low frequency response is shown by the ability of the amplifier to reproduce a low frequency square wave without rounding or tilting of the waveform, or a combination of both of these effects.

The presence of non-linear distortion in an amplifier, when pulsed by square waves, is indicated by the output wave being symmetrical with respect to time, but the positive and negative half cycles are asymmetrical. This effect is usually not noticeable unless ringing exists. If the amplitude of the damped oscillation is different for the top and bottom of the wave, non-linear distortion is present. In general square waves are not useful in the determination of harmonic distortion, because the large number of frequencies present in the test signal serves to mask the production of other frequencies by the non-linear transfer characteristic of the amplifier.

In Figure 1 are shown the square wave responses, under the indicated conditions, for the Western Electric Type 124 amplifier, and the Williamson amplifier (discussed later in this article), using the Peerless 265Q and

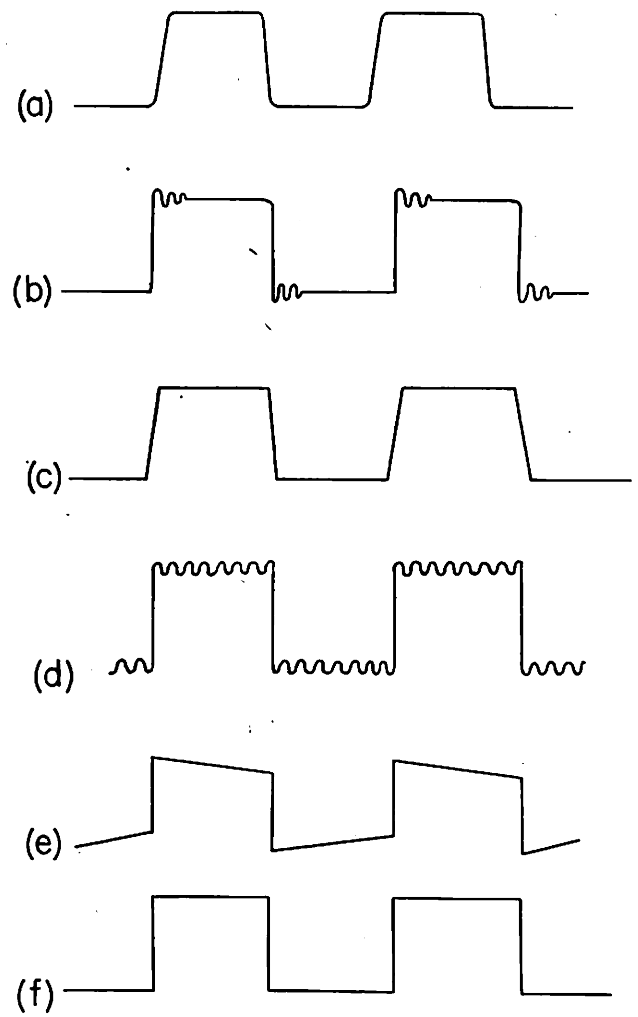

FIGURE 1—Qualitative sketch of output wave shape for square wave input—Western Electric and Williamson amplifiers.

(a) Western Electric Type 124 amplifier, using Western Electric Type 171C output transformer. Period of input square wave is 1/10,000 second. Although the rise time is appreciable (as shown by the sloping sides of the wave) there is no evidence of ringing.

(b) Williamson amplifier using Peerless Type 265Q output transformer. Period of input square wave is 1/10,000 second. Ringing, due to transformer resonance, is apparent.

(c) Same as (b) except 0.27-megohm resistor is connected in series with grid of input tube.

(d) Williamson amplifier using Partridge W.W.F.B. /0/1.7/ output transformer. Period of input square wave is 1/10,000 second. Violent ringing exists.

(e) Same as (c), except period of input square wave is 1/20 second. The negative slope of the top of the wave indicates low frequency amplitude or phase deficiencies.

(f) Same as (d), except period of input square wave is 1/5 second. The low frequency characteristic of this amplifier is phenomenal!

Partridge W.W.F.B. /0/1.7/ output transformers. Ring is cured in both Williamson amplifiers by connecting a resistor of suitable value in series with the grid of the input tube. This resistance in combination with "Miller Effect," i.e., the effective capacitance of the input tube, provides the necessary gradual taper of the frequency response characteristic at the high frequency end of the transmission range to remove the ring. Of course the corners of a square wave having for example a fundamental frequency of 10 kc are not as sharp as before because the filter naturally has a deleterious effect on the frequency response of the amplifier. Sometimes there must be a compromise between steepness of wave front and excessive oscillation or ringing.[2] Practically all amplifiers, including the widely acclaimed "McIntosh," ring to a certain extent. But this is not a normal state of affairs.

The writer feels that it is not amiss for the purchaser of an amplifier which supposedly has a flat frequency response characteristic to insist on viewing its output wave form when driven by a square wave generator. But be sure not to expect an equalizer, or tone control circuit to pass undistorted square waves!

Harmonic and Intermodulation Distortion—Manifestations of the Same Phenomenon

Harmonic and intermodulation distortion are caused by one and the same thing—the non-linear transfer characteristic of the amplifier. If the shape of the transfer characteristic is known, it is a simple matter to write an equation for the output current wave of the amplifier, when it is excited by sinusoidal voltage source. If the output current wave contains harmonics of the frequency of the driving voltage, the amplifier transfer characteristic is non-linear. This very same amplifier, if driven by a linear synthesis of two sine waves of different frequencies, will give rise not only to harmonics of the applied voltage, but sum and difference frequencies as well. The analysis of this phenomenon is trivial, and does not involve more than high-school trigonometry. Thus without difficulty one may write an equation for the output current wave for two simultaneously applied sine wave exciting voltages. The harmonic distortion meter takes account of the terms in this equation containing harmonic frequencies, while the intermodulation distortion meter takes account of the terms in the expression involving sum and difference frequencies.

If it is assumed that:

1—The amplifier transfer characteristic is independent of frequency—a good approximation in practice.

2—The same total peak driving voltage is used for both the harmonic and intermodulation distortion tests—so that the amplifier will be operating within the same limits of input voltage and output current.

3—The ratio of the sinusoidal low frequency voltage to sinusoidal high frequency voltage is 4 to 1 (12-db differential),

then it can be demonstrated that relatively fixed ratios for intermodulation to harmonic distortion exist. These ratios are about 3.2 to 1 for a single ended amplifier, and about 3.8 to 1 for a balanced push-pull amplifier.[3]

It is clear then that harmonic and intermodulation distortion are manifestations of the same phenomenon. From a complete knowledge of the amplitude and frequency of the harmonics generated by an amplifier when a single frequency voltage wave is applied, one can determine analytically the percentage of intermodulation distortion that will result when two sinusoidal voltages of different frequency are applied to the input terminals of the amplifier. Anything that is done to reduce harmonic distortion automatically reduces intermodulation distortion. The relations involved are mathematical laws, which within their sphere have the same immutable character as the physical law which prohibits the building of a successful perpetual motion machine. As is well known by persons who have specialized in the design of such machines—there is always just a little something the matter. So anyone who tries to reduce intermodulation distortion without reducing harmonic distortion in a given amplifier will find his efforts are doomed to failure. The crux of the matter is this: Use every conceivable device to reduce harmonic distortion in the sound system, and intermodulation distortion will minimize itself.

Usually harmonic distortion measurements on amplifiers are made at 400 cycles per second, so that a large number of harmonics produced will lie within the pass band of the amplifier—and distortion meter—and thus be available for measurement. If harmonic distortion is determined at 400 cycles per second nothing is known about high frequency harmonic distortion. Even though the distortion components of the high frequency signal may be inaudible, intermodulation products are produced which may lie in the transmission band of the equipment. A point in favor of the intermodulation distortion meter is that it need operate only in the pass band of the amplifier under test. But the harmonic distortion meter must operate over a very wide frequency range—often entirely above the pass band of the amplifier if quantitative measurements of very high frequency distortion are to be made. Since the ratio of intermodulation to harmonic distortion, as customarily determined, is about 4 to 1, it would appear that the intermodulation method for measuring distortion is more sensitive than the harmonic distortion method.

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[2] Mr. Robert M. Mitchell in his paper entitled "A Wide Range Feedback Amplifier" (Radio and Television News, Page 66, October 1950) refers to his Figure 8A and makes the following statement: "The small oscillations on the top of the square wave pattern are due to the shock excitation and are quite normal. They are of small amplitude and have no effect on the amplifier performance in the audio range."

From an examination of Figure 8A, based on the writer's experience with the Williamson circuit, it is concluded that at the high frequency end of the transmission band abrupt deteriorations take place in the amplitude and phase response of the amplifier caused by resonance in the UTC LS-63 transformer. Transformer resonance is often responsible for ringing.

[3] If the analysis is based on equal amplifier power output, for the two conditions of test, these ratios are no longer valid.

Western Electric Amplifiers: Circuit Modifications and Response Data

Certain circuit modifications in the Western Electric amplifiers types 124, 142 and 143 have been made by the Bell Telephone Laboratories to improve their performance.

Western Electric Type 124 Amplifier

Refer to BuShips Electron, December 1948, Page 21, Figure 2. When the circuit is built around a Western Electric Type 171C output transformer, eliminate resistors R12, R18 and R19, and capacitors C7 and C11. Resistor R5 is changed from 0.25 megohm to 0.24 megohm, and resistor R6 is changed from 0.25 megohm to 0.18 megohm. The capacitor C10 is selected to obtain the desired response, but its value is never greater than 0.02 mf. The writer has always used a 0.2 mf condenser as C10. For the 20-watt connection reduce resistor R 10.1 to 180 ohms, and multiply the columns headed "Nominal Load Impedance" and "Working Range Load Impedance" by the factor 2/3.

When a Peerless Type 265Q transformer is used in lieu of the Western Electric Type 171C transformer, it is recommended that the above changes in the circuit be made, with the exception that resistors R18 and R19 be retained if the amplifier proves to be unstable.

The frequency response of the amplifier, when connected for 12 watts power output, was measured using an oscilloscope to detect wave form distortion. Harmonic distortion of about 3% or more can be estimated in this way. The data, when plotted, is the power curve of the amplifier. The rated power output of 12 watts corresponds to 0 db. Unless specifically noted, no waveform distortion is visible.

The measured harmonic distortion of the Western Electric Type 124 amplifier is 0.7% at 400 cycles per second for 12 watts output. An advantage of this amplifier is that only two stages are needed to obtain some 50 db gain. It is to be remembered that distortion is cumulative and increases as more distortion producing stages are cascaded.

The data in Table 3, when compared with the data in Table 2 illustrates the high frequency attenuation caused by the protective network C7, C11 and R12.

Table 1

Frequency response Western Electric Type 124 amplifier, with recommended circuit modifications, using WE 171C transformer. The load impedance is 7.5 ohms.

Frequency in cycles per second	Power output db (0 db is 12 watts)	Remarks
20	— 0.5	waveform distorted
25	0	waveform excellent
25 to 1000	0	
2000	0.5	
10,000	0.75	
15,000	0.5	
20,000	0	
40,000	— 3.0	
55,000	—10.0	

Western Electric Type 142 Amplifier

Refer to BuShips Electron, December 1948, Page 22, Figure 3. To protect the amplifier under conditions of no load or very light load, the following circuit changes should be made: Connect a 0.022-mf capacitor between Terminals 7 and 8 of the WE 519A output transformer. Connect a 10,000-ohm 2-watt resistor between Terminals 9 and 10 of the same output transformer.

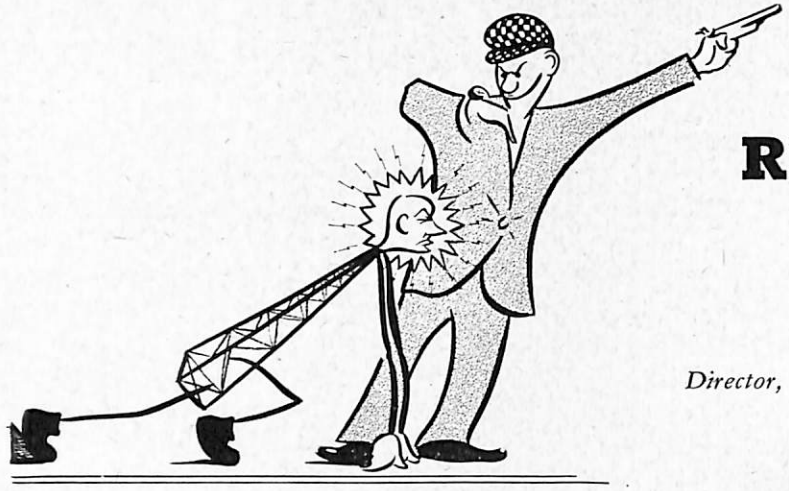
The high frequency response of the amplifier is greatly affected by the choice of R29 and C13. In the factory built amplifiers R29 is 1000 ohms and C13 is 0.002 mf.

Table 2

Frequency response Western Electric Type 124 amplifier using Peerless Type 265Q output transformer. Resistors R18 and R19 are included in the circuit, but all other recommended circuit modifications are made. The observed waveform is excellent for all frequencies. The load impedance is 4 ohms.

Frequency in cycles per second	Power output db (0 db is 12 watts)
20	1.0
50	0.5
200—2,000	0
9,000	1.5
20,000	0.25
28,000	— 1.0
30,000	— 2.0
40,000	— 3.0
53,000	— 5.0
70,000	—10.0

(Continued on page 22)



RADIO STATION READINESS

by

Captain H. B. Morris, USNR

Director, Electronics Shore Division, Bureau of Ships

In the midst of flooding remarks by columnists and critics which have been more or less derogatory to the state of material readiness of the Armed Forces, it is a pleasure to be in position to point with pride to more than "paper" preparedness at the Navy's important shore communication plants.

With annual inspection recently completed at the Annapolis transmitting station, we find the "Well Done" pennant in full breeze in the form of a commendatory letter over the signature of Admiral Sherman quoted in part as follows:—". . . the Commanding Officer and personnel are commended for their efforts in achieving and maintaining an excellent material condition during the past fiscal year."

It is to be recognized that the maintenance crews under the guidance of the Electronics Officer at the Naval Gun Factory, Anacostia, have contributed greatly to this excellent record and both station and shop have given evidence of team work spirit to produce such a record.

Among the factors contributing to readiness and excellent house-keeping are such seemingly trivial matters as keeping up with all field changes, keeping electrical connections, bonds and grounds in proper condition to eliminate interference sources, adequate preventive maintenance schedules faithfully and intelligently pursued, and proper attention to the ever necessary training programs.

Annapolis Radio Station, along with most all of Naval communication facilities, does not boast of having all of the equipment required to meet full mobilization for the area served. Limited funds for shore station procurement over recent years has not permitted such realization. But it is nevertheless with gratification that we can point to an efficient ship shape facility manned by personnel imbued with the traditional pride of the service, and condition readiness excellent.

MODEL DAS REMOVABLE HOOD

The removal of outside glare from the scope of the Model DAS series equipment may be accomplished by the use of a removable extension hood. It can be mounted while a reading is being taken and then removed. Such a hood should be used only on equipments where the present hood does not provide adequate light shielding.

The removable hood shown in Figure 1 was suggested by Albert G. Thompson of the Puget Sound Naval Shipyard.

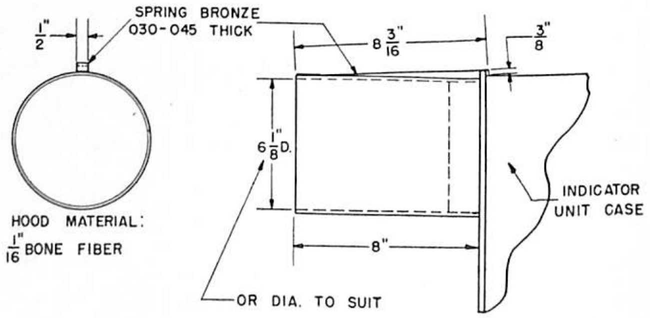


FIGURE I—Removable hood for the Model DAS equipments, to remove outside glare.

Clean equipment is usually properly-operating equipment.

MAINTENANCE OF MODEL DBM–I ANTENNAS

Page 26 of the June 1949 BuShips Electron Magazine described a method of repairing Model DBM and DBM–1 antenna spinner bases which have broken hubs.

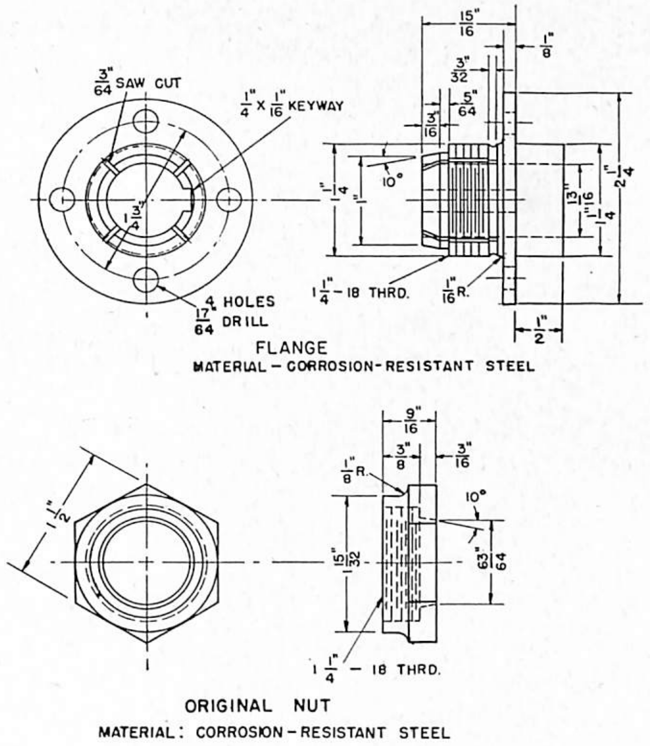


FIGURE I

This method has been found to be unsatisfactory due to the excessive stress placed on the four mounting screws holding the new hub.

An improved type of hub is shown in Figure 1. It differs from the original modification by the addition of the $1\frac{1}{4}''$ collar and a larger flange. The hub shown in Figure 1 should be machined from corrosion resistant steel. The nut shown is the original locking nut. The spinner base must be bored to take the $1\frac{1}{4}''$ collar of the hub and then counterbored $\frac{1}{8}''$ for the $2\frac{1}{4}''$ flange. Four matching holes must be drilled in the spinner base and the hub attached by means of four screws, nuts, and lockwashers. Whenever possible, this repair should be effected rather than the replacement of the entire unit.

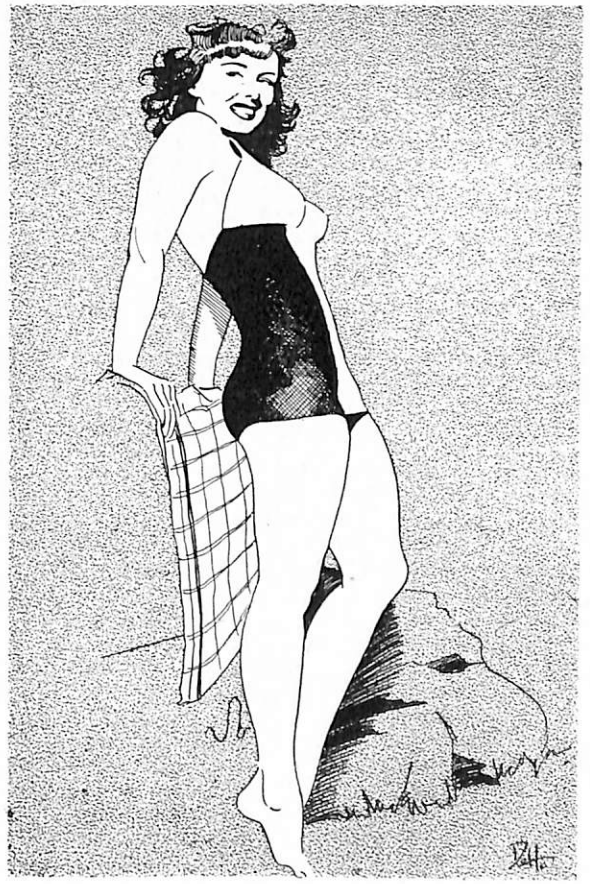
The improved hub plan was received from A. F. Carroll, RMC, USN.

REPLACEMENT OF JT HYDROPHONE BRASS BOLTS

A recent report received by the Bureau of Ships states that while a submarine was engaged in submerged exercises and running at a speed of 11 knots, the JT hydrophone was carried away. The hydrophone was trained at 120° relative at the time. A later examination of the shaft disclosed that the two cap screws were sheared and corrosion on portions of the sheared surfaces indicated that partial shearing had occurred previously. It was further disclosed that the screws were made from brass stock instead of stainless steel as originally supplied by the manufacturer, and identified by symbol H–1201 and RCA drawing and part number 131401 in the JT Instruction Book, NAVSHIPS 900,424A.

Article 2.13 of the Sonar Bulletin cautions installation activities against the substitution of brass bolts for those of stainless steel.

NEXT MONTH



THIS will not appear next month, but a revealing article "UHF Can Work" will be in the April Electron.

nel notes: automatic weather station

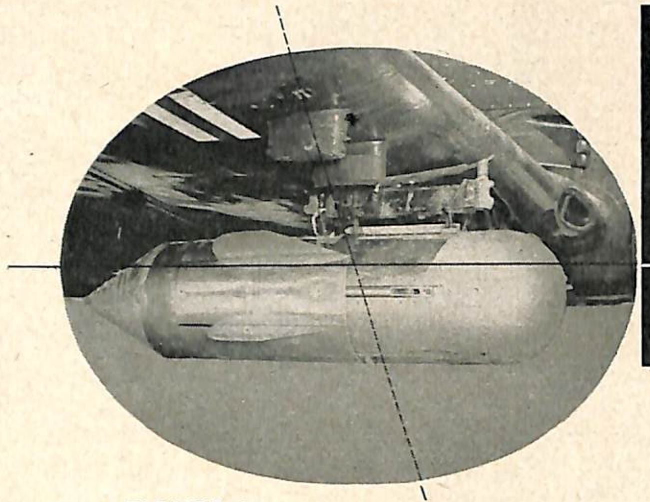
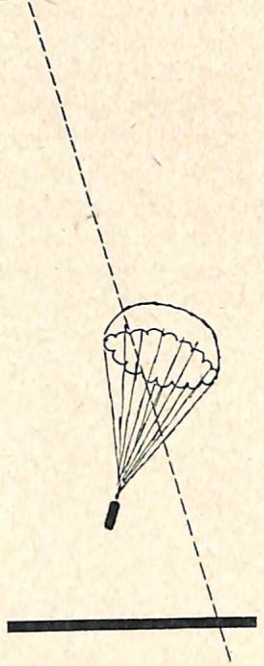


FIGURE 1



One of the latest additions to the Navy's list of navigational aids is an expendable automatic weather station developed at the U. S. Navy Electronics Laboratory. The station is designed to be carried by aircraft and dropped by parachute at remote, inaccessible points or in areas held by the enemy. Once it has reached the ground, the unit erects itself to an upright position and begins its transmission of weather data on a high-frequency radio link.

The complete station fits in a bomb-type metal cylinder which may be carried on regulation aircraft wing racks (Fig. 1) or in bomb-bay racks. It carries (1) a self-contained power supply, (2) a radio transmitter, (3) instruments for measuring atmospheric pressure, air temperature, relative humidity, wind direction, and wind velocity, and (4) a timing mechanism which automatically controls the setting up of the station after a drop and provides for the automatic radio transmission of meteorological information at regular, round-the-clock intervals.

Erection of the automatic weather station after it has reached the ground is delayed by a timing device for enough time to allow the unit to roll to rest. The timing device then releases a charge of compressed gas that actuates a mechanism by means of which six legs are extended to bring the cylinder to an upright position. The 13.5-foot telescoping whip antenna is then erected and the electronic circuits are turned on.

The automatic weather station includes a timing clock which establishes the schedule on which information is sent out. Once every six hours, or at other predetermined intervals, information is transmitted for a period of three minutes. Each station can be identified by its unique transmission schedule; in addition, each station transmits an identifying code letter by which it can be distinguished from another station.

A coding mechanism takes information from the five weather elements and translates it into characters of the Continental Morse code. Weather data is transmitted in 3-letter code groups in which the first letter indicates the weather element and the last two give the value. The particular combination of letters transmitted is controlled by a selector mechanism which is rotated by a 2-phase motor. The motor is actuated by having an amplified a-c signal applied to one winding while the voltage applied to the other winding is of constant phase. The amplified signal is the result of an unbalanced condition existing in a resistance bridge, one leg of which is a variable resistance controlled by the weather element involved. Balance is restored to the bridge by the 2-phase motor rotating a potentiometer until the output of the bridge is zero. At this time the driving voltage to the motor is zero and equilibrium exists. The output of the coding mechanism keys the battery-powered, 15-watt, cw transmitter, which operates on a frequency of 5072.5 kilocycles. The transmitted signals can be read by any radio operator using standard receiving equipment.

The humidity-measuring device is a standard, commercial item which was adapted to this use. The pressure-measuring instrument was built to specifications by a commercial firm working under contract. The wind-speed, wind-direction, and temperature-measuring devices were developed by the Navy Electronics Laboratory.

Figure 2 shows the weather station set up and the antenna extended. Figures 3A, 3B, and 3C reveal the construction inside the cylinder. The electronic components are located in the lower section and, under actual operating conditions, are fully protected by weather shields. The weather-measuring instruments are contained in the upper section of the unit, which is open to the weather through a perforated metal shield.

The station is aerodynamically stable at carrying speeds up to 360 mph; is able to erect itself on slopes up to 45 degrees; will withstand wind velocities up to 80 knots; and will function in temperatures ranging from —70 to +110 degrees Fahrenheit. During tests, the station operated for a period of two weeks under conditions of snow and rain in the Sierra Nevada Mountains, achieving successful 500-mile transmission. Final successful drop tests have been made at the Navy Parachute Experimental Unit, El Centro, California.

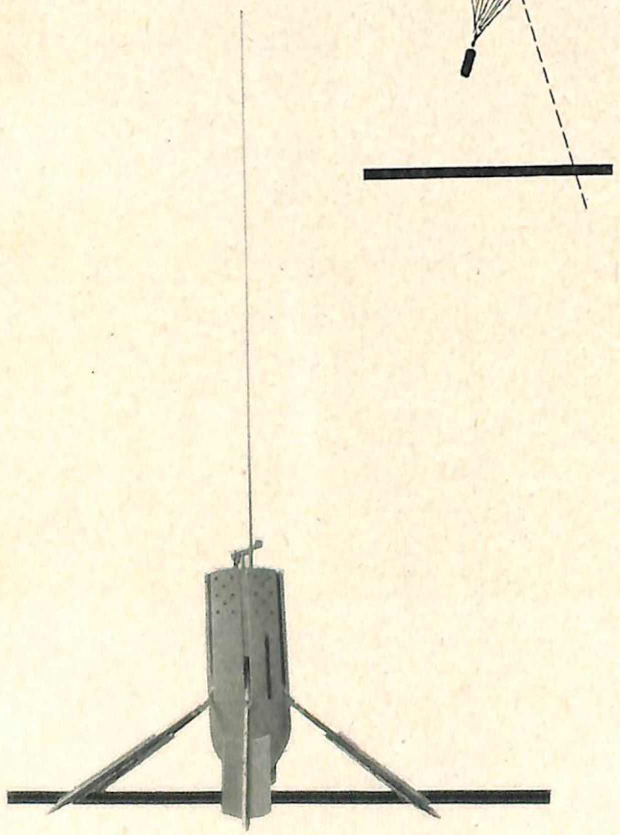


FIGURE 2

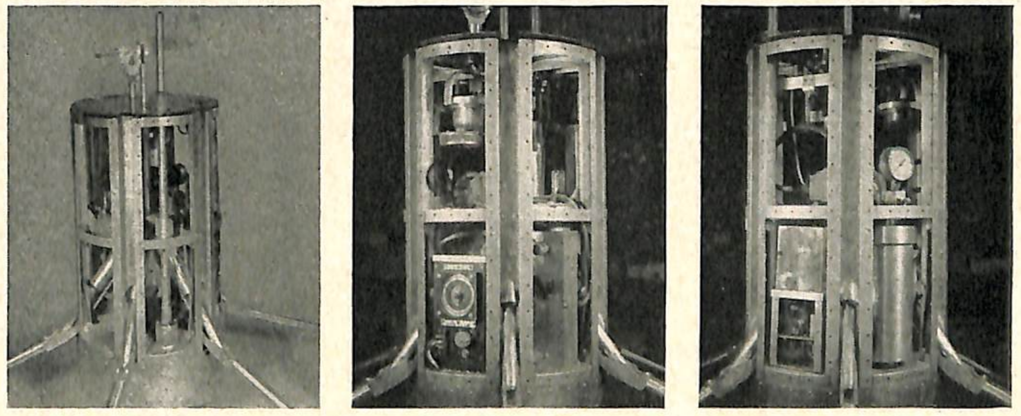


FIGURE 3—Three views of the automatic weather station with weather shields removed. Lower half of cylinder contains electronic components, which are normally fully protected by shields. Upper half contains meteorological instruments, which are exposed to weather through perforations in shields.

COMMON TROUBLES IN MODEL SA SERIES RADARS

by

C. F. Thompson, *Philco Field Engineer*

Experience over an extended period of time with the Model SA series radars has resulted in the accumulation of numerous common failures and troubles in these equipments. In the interest of other technicians who are responsible for servicing these equipments, these common troubles and failures are listed below.

Radar Transmitters

Failure of the 8014 type transmitting tubes has been the largest source of trouble in the transmitter. By following the test procedure set forth in RMB, good tubes can be selected. Testing your spare tubes is not a bad idea either.

A common practice is to remove the plates E–122 and E–103 over the filament leads to prevent shorting of the filament leads to the transmission line. These form a part of the tuned cathode circuit and must be mounted on the ends of the tuned lines. In addition, the three spherical head mounting screws should be in place to prevent this shield from shorting to the filaments. A reading of 5.5 ohms should be obtained from the filaments to ground.

Frequently the blower supplying air to cool the transmitting tubes accumulates sufficient dust to restrict the air flow. Cleaning with a dry brush will remedy this. Often the baffle on the blower deflects the air stream above and below the transmitting tubes rather than directly on the plates giving rise to high mortality rates.

The grid tuned lines often are corroded and pitted from making poor contact on the 8014's and should be cleaned or replaced to prevent further arcing.

Frequent checks should be made on the transmitter filament voltage to see that the filament voltage is actually 14.3 volts. The primary voltage should be read and recorded on M–102 and the filament voltage adjusted to this reading after the transmitter is radiating.

External Duplexer

The most common sources of trouble with the duplexer consists of dirty cavities and pitted spark electrodes. Monthly cleaning of the cavities and electrodes keeps the duplexer in peak operating condition.

OAA–2 Radar Test Set

Frequent failure to obtain maximum power output of the transmitter has been attributed to a general lack of use of the OAA–2 when tuning the transmitter. Another failure has been in the pick-up antenna for the OAA–2, which has been found to have shorted coaxial cables, broken insulators, and even no antenna at all.

Radar Receiver

The receiver input cable from the TR cavity has failed frequently resulting in a considerable reduction in signal amplitude. Poor ground connections and lack of setscrews in the connectors are the biggest offenders here.

The 6AC7 i-f amplifiers are common sources of trouble and should be checked frequently as should the GL–446 Lighthouse tubes. A quick check on the latter is for a 1.5 to 2 volts drop across R–1402 and R–1401, the cathode resistors. (To prolong the life of the GL–446 tubes, R–203 has been changed from 1k to 5.6k ohms. It has been found that this change has not been made on all SA's.)

Deflection Amplifier

Several cases revealed that field changes had not been made resulting in short sweeps on the "B" and "C" ranges. Merely changing R–322 from 100k to 10k ohms cures this. In addition, it is possible that Field Change No. 28 will remedy a short sweep on the "C" range as well as to improve focusing of the indicator.

Poor focus of the pulse indicator V–309 has been caused by a weak 902 (2AP1) tube, by R–435 changing value, or by a weak 2x2 rectifier.

Indicator Unit

Field Change No. 41 is missing on many SA's. This provides for a fused primary of T–402, the high voltage rectifier plate transformer. Frequent shorts and gassy 2x2's have caused many failures of this transformer and it is recommended that the change be made as soon as possible.

Short sweeps on all ranges have been caused by a weak 6AC7 in V–407 socket, the sweep phase inverter.

Train Indicator Control Unit

Slewing motor B–1002 has failed in several cases. Generally an open field winding is the trouble but open wiring has caused this symptom. When replacing, be certain that the correct replacement is obtained. (SA–3 has 40/85 rpm motor while SA–1 and –2 have a 45/18 rpm motor.)

The plate variac T–1002 has given considerable trouble. (See RMB.)

Train Control Amplifier

Adjustment of the amplifier according to the instruction book will generally remove jitter of the antenna and allow it to follow the training handwheel. However, if continuous rotation of the antenna occurs with the emergency train switch (S–1006) in the "auto" position and with the slewing motor control (S–1003) in the "off" position, trouble is usually due to unbalanced 808's or 8005's. An opening in grid or plate leads has also produced unbalanced amplifiers as have shorted 808's. The 6x5 rectifier (V–506) has failed in several cases giving no antenna rotation.

Plan Position Indicator

Several cases of poor focusing of the PPI have revealed shorted cathode-ray tubes. Generally pins 3 and 7 are the most likely to be shorted on the 7BP7 (V–1220).

Frequent tube failures in the saw-tooth generators and amplifiers V–1201 through V–1208 have been found. This produces a sweep with an origin that oscillates back and forth on either the N–S or E–W axis.

Failure of the input multivibrator to synchronize with the transmitter allows video to run in and out on the sweep. This was traced to the radar transmitter where E–122 had shorted to a filament lead of an 8014 transmitting tube giving a 60-cycle sine wave and a small trigger pulse as "sync" to the PPI.

Servicing of the PPI is simplified if the range indicator video input cable is removed and used to supply waveforms to the "A" scope.

Bearing Amplifier Converter

Tube failures in the servo amplifier are the most frequent cause of trouble in this unit. Proper adjustment of the servo gain control is for smooth rotation of the PPI trace without the trace lagging behind the "bug" on the training indicator. Oscillations of the PPI sweep with the antenna stopped, indicate too high a gain setting of the servo gain control.

Failure of the microswitches S–1301 through S–1308 have caused the most trouble with the sector scan system.

Radar Antenna and Pedestal

A frequent source of poor echo return has been attributed to rusted antenna assemblies. In most of these cases the dipoles have been rusted to the point of disintegration. Inspection of antenna assemblies to determine if oxidation is present under the paint is recommended. If present, removal of rust and repainting will generally prevent serious failures.

Several instances have occurred where the radar antenna has been replaced due to excessive rusting of the dipole elements. When a new or reconditioned antenna is installed, a thorough check should be made before installation to see that the new antenna is for the same band as the old antenna. It is imperative that the new antenna, even if it is the same band as the old, is adjusted in accordance with the dimensions given in the "L–R Switching Box Tuning Chart."

The antenna drive motor armature has been found to bind occasionally. Investigation revealed that the bearing grease seal adjacent to the blower motor was oversize and had bound in the bearing housing. This applies especially to motors with serial numbers lower than 633506. A 0.015 inch cut of the bearing shield with the armature set up in a lathe will remedy this trouble.

—*ServLant Monthly Bulletin*

The Editor of ELECTRON is anxious to solve your tough problems, if you will send them to him. See "Letters to the Editor," on Page 32 of this issue for a sample. *Let him help you!!*

TESTING COPPER OXIDE RECTIFIER STACKS

Copper oxide rectifier units used under normal operating conditions will give long trouble free service, and periodic checking of the rectifier d-c output voltage is sufficient to determine the condition of the rectifier.

Under severe service conditions of high temperature, high humidity and salt atmosphere, it is recommended that periodic tests be made of the forward and reverse current characteristics of individual rectifier stacks. These tests can be made by connecting individual stacks as illustrated in Figures 1 and 2. The recommended applied voltages and currents to be expected can be read from the table. Before making these tests the rectifier should be de-energized for several hours and allowed to reach room temperature (70°F to 80°F). High temperatures will have the effects of increasing both the forward and reverse current. Low temperatures will reduce these currents.

Transmitter Model	Rectifier Type	Rectifier Stack		Forward Fig. 1		Reverse Fig. 2	
		Symbol	Mfr. Designation	Test Voltage	Amperes (Minimum)	Test Voltage	Milliamperes (Maximum)
TAB-6/7 TBU-4	CAY- 20167	CR-701/718	S#1292367	232	0.5	348	7.0
		CR-719/722	S#1292368	160	0.5	240	7.0
		CR-723 (*)	S#1292369	80	1.0	120	14.0
TBL-10/11	CAY- 20195	CR-701/706	S#1303807	200	0.5	300	7.0
		CR-707/710	S#1292368	160	0.5	240	7.0
		CR-711 (*)	S#1292369	80	1.0	120	14.0
TBM-10 TBK-16	CAY 20228	CR-901/915	S#1303807	200	0.5	300	7.0
		CR-916/919	S#1312218	240	0.5	360	7.0
		CR-920 (*)	S#1315048	88	1.0	132	14.0

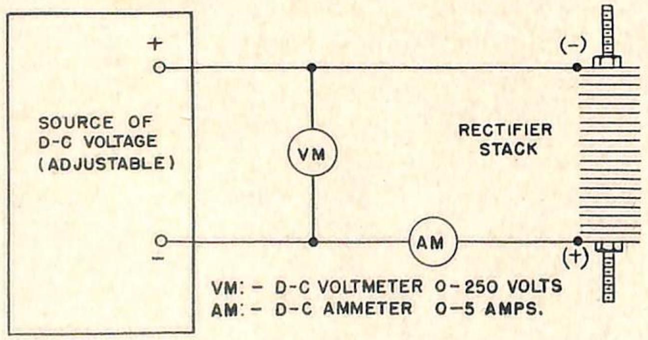


FIGURE 1.

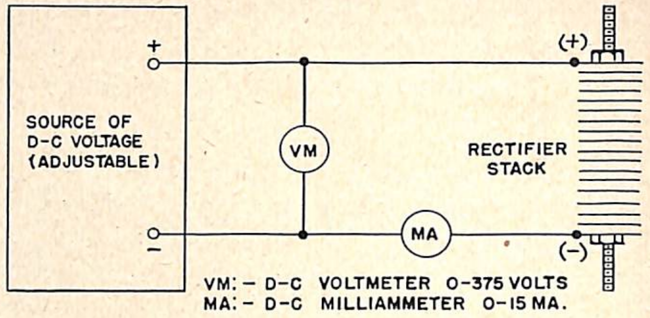


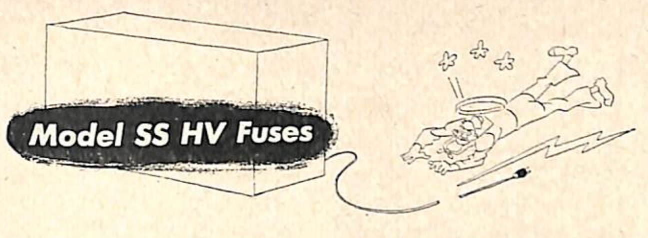
FIGURE 2.

Resistance measurements obtained with an ohmmeter, Wheatstone bridge or megger are of little or no value, unless the stack is short circuited or open circuited.

FIELD CHANGE INSTRUCTIONS

Field change instructions, diagrams, data for correcting instruction book pages, etc., are included in every field change kit. If the ship makes the change these sheets should be placed in the instruction book or somewhere accessible to the technicians. If a shipyard or tender makes the change the sheets are supposed to be delivered to the Electronics Officer. It is very rare to find these sheets in the instruction books and when trouble develops around a field change you can imagine the confusion, as the original prints no longer apply. Make certain those field change instruction sheets receive the proper care and disposition. Electronics Officers should search their files, safes, etc. to see if missing data is actually on board the ship. It is a direct responsibility of the ship to insure that every change in the equipment is accounted for by proper diagrams.

—*SubFlotOne Newsletter*



Model SS HV Fuses

Very often the HV fuses in the Model SS radar blow for no apparent reason. This can be tied down to one of two troubles. It is nearly always due to defective 836 tubes in the high voltage rectifier. If not the 836's, the second choice is one of the 5D21 tubes in the transmitter. A simple test is as follows:

Disconnect the insulated wire from Terminal 19 in the SS transmitter.

Turn the transmitter switch ON.

Since the HV will now be from 1800 to 2000 volts instead of the normal 1250, a weak or defective 836 tube will cause fuses F3 and/or F4 to blow. If these fuses do not blow then the 836's can be considered good and attention can be centered on the SS transmitter.

Ground the wire removed from Terminal 19 *after turning off the transmitter* otherwise a dangerous charge will remain on the filter capacitors for a long period of time.

Reconnect the wire to Terminal 19. Remove the 5D21 tube and place the transmitter in operation. You will probably discover that one or both of the 5D21's are arcing internally which results in fuses blowing. Modulation network trouble or something associated with the 807 output in the modulation generator are additional sources of trouble but only in rare cases.

—*SubFlotOne Newsletter*

Bureau Comment: Technicians are cautioned to adhere strictly to Bureau-approved methods for measuring high voltages as outlined below:

Voltages over 300 volts shall be measured as follows:

1—Deenergize the equipment. Ground terminals to be measured to discharge any capacitors connected to these terminals. (See Note F.)

2—Connect meter to terminals to be measured using a range higher than the expected voltage.

3—WITHOUT TOUCHING METER OR TEST LEADS, energize the equipment and read the meter.

4—Deenergize the equipment. Ground the terminals connected to the meter before disconnecting meter.

NOTES:

a—MAKE SURE you are NOT GROUNDED whenever you are adjusting equipment or using measuring equipment.

b—In general, USE ONE HAND only when servicing live equipment.

c—If test meter must be held or adjusted while voltage is applied, GROUND the case of the meter before starting measurement and DO NOT touch the live equipment or personnel working on live equipment while you are holding the meter. Some moving vane type meters should not be grounded. These should not be held during measurements.

d—DO NOT FORGET that high voltages MAY BE PRESENT across terminals that are normally low voltage, due to equipment breakdown. Be careful even when measuring low voltages.

e—DO NOT use test equipment known to be in poor condition.

f—High-voltage high-capacity capacitors should be discharged with a grounding stick with approximately 10 ohms in series with the grounded line. Where neither terminal of a capacitor is grounded, short capacitor terminals to each other.

MODELS SS AND SV NOTES

R(L)17 Failure

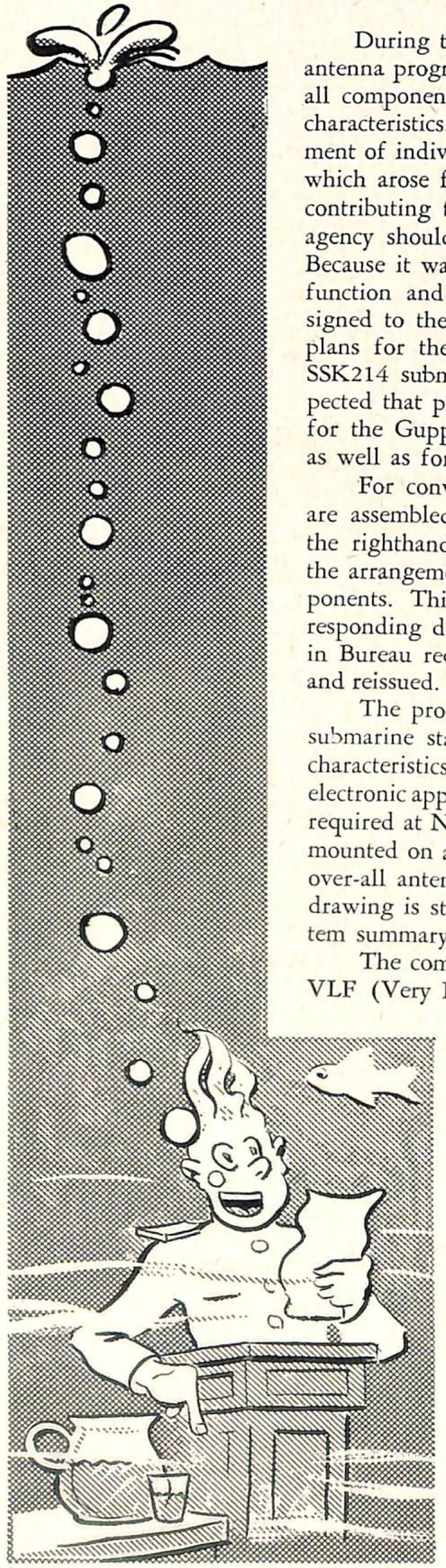
Resistor R(L)17 (68 ohms) in the console unit under the adjustment panel is often found burned or cracked due to excessive current. It appears as though this trouble is a direct result of the positive grid voltage on the deflection amplifiers V1 and V2. The resistor is in the cathode circuit of those tubes and it can be seen that more than a few positive volts on the grids will cause the resistor to carry an excessive current. If you have this trouble try measuring the grid voltage on V1 and V2. The positive voltage can be due to one of several troubles. Capacitor C2 in the grid circuit of V2 isolates the grid from the plate voltage of the pre-video amplifier and if this capacitor is leaking it will naturally allow the grid of V1 and V2 to become positive. A positive voltage from the bearing osc/detector circuit will do the same thing and can be checked at J10A and J10B.

False Echoes or Multiple Pulses

Several instances have been reported and observed in which multiple pulses or false echoes appear on the SS and SV radars. The actual appearance as seen on the scope is a second pulse or multiple pulse to follow the transmitter pulse or in some cases appears as an extremely wide transmitted pulse. A defective 719A clipper tube in the SS or defective 705A clipper tubes in the SV have been found to be the cause of this trouble.

—*SubFlotOne Newsletter*

USN USL notes



During the past two years, the emphasis in the Underwater Laboratory's submarine antenna program has been placed upon the design of complete antenna systems, in which all components are specially designed or selected to provide optimum system operating characteristics. Previously, the Laboratory had been responsible only for the development of individual antennas and transmission line fittings. After a number of difficulties which arose from the lack of complete information on the part of the various agencies contributing to final submarine antenna system designs, it was obvious that some one agency should be assigned full responsibility for the coordination of all system data. Because it was in an excellent position to undertake the responsibility, the coordination function and the study and design of complete submarine antenna systems were assigned to the Laboratory. During the past year the Laboratory has developed detailed plans for the antenna systems to be installed on the SSK1 to 3, SS563 to 568, and SSK214 submarines, all of which are now in various stages of construction. It is expected that plans will be prepared in the near future for the design of antenna systems for the Guppy 1A class and subsequently for several other classes of new submarines as well as for the modernization of the antenna systems of existing submarines.

For convenience, the submarine antenna system plans prepared by the Laboratory are assembled and distributed in file folders. Each summary consists of two sections; the righthand pages contain typewritten information while on the left are sketches of the arrangements, schematics of individual systems, and drawings of USL-designed components. This arrangement permits the reader to refer readily to a drawing and its corresponding descriptive material. As additional information, new equipment, or changes in Bureau requirements become available, the appropriate sheets are altered accordingly and reissued. Changes from previous issues are indicated by asterisks.

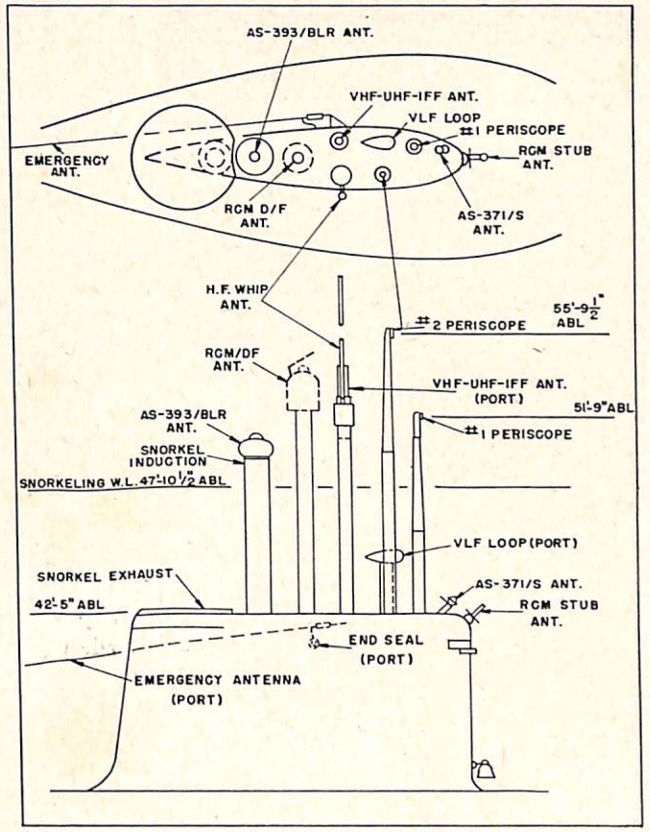
The process of developing a summary of antenna systems for any type or class of submarine starts when the Chief of Naval Operations draws up the required military characteristics. The Bureau of Ships interprets these characteristics in terms of specific electronic apparatus, antennas, and methods of mounting. Thus, if u-h-f communication is required at No. 1 periscope depth, the Bureau will specify that the u-h-f antenna must be mounted on a retractable mast. The Bureau then prepares a drawing showing a proposed over-all antenna system, but does not provide details for the required components. The drawing is studied at the Laboratory and forms the basis for preparing the antenna system summary.

The complete antenna system is broken down into independent sub-systems, such as VLF (Very Low Frequency) and the RCM (Radar Countermeasures) sub-systems, and a schematic sketch and a detailed list of materials for each sub-system is prepared. Additional general information and an outboard plan and profile sketch are assembled into a summary.

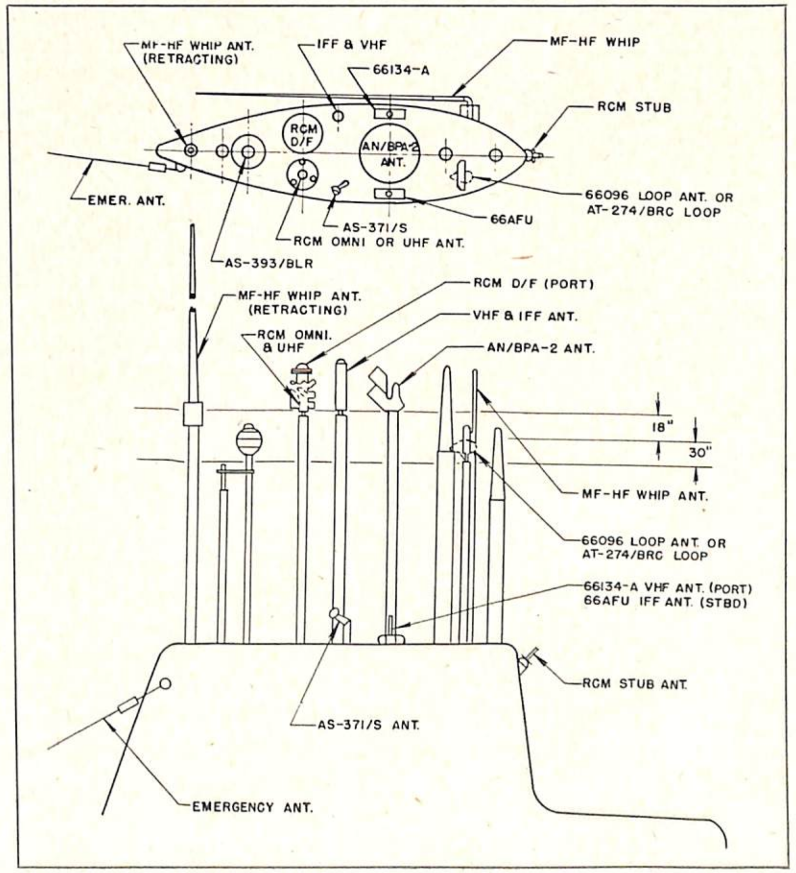
Copies of the summary are distributed to the Bureau of Ships and to the shipbuilders concerned. Subsequent comments obtained through correspondence and conferences are considered, and justifiable alterations are made in the summary. The summaries have proved valuable in indicating where additional development work is required or where some decision or agreement must be reached. An example of the former was the discovery that the loading coil for the Model DAS–4 (Loran) equipment requires modification for use with coaxial cable. It is doubtful whether this fact would have come to light had not the summary been prepared; in all probability, the installation would have been made with an open connection, thus permitting interfering noise to be picked up.

An example of a situation wherein an agreement had to be reached is that involving the HF receiving antenna transfer panel. Originally, the Bureau had proposed an HF receiver-only multicoupler. When it appeared that the multicoupler would not be developed in time, the problem was studied at the Laboratory. It was decided that a patchboard would no doubt, satisfy the requirement, and a design using RG–58/U cable was prepared. On the basis of the Bureau's desire to standardize on RG–10/U cable, the design was changed. Subsequently, a design already in service, which also appeared satisfactory, was proposed by the Portsmouth Naval Shipyard, and eventually a design which is apparently satisfactory to all concerned was evolved by the Bureau. The USL summary has been changed to specify the new design, and the shipbuilders (Electric Boat Company and Mare Island Naval Shipyard) have been designated to produce the proposed system. The Laboratory designates the manufacturers and determines which components they are to furnish. Unless there is some valid objection on the part of either the Bureau or the shipbuilder, this designation is allowed to stand. Where there is any disagreement, the Bureau makes the final decision, and the summary is changed accordingly.

When the antenna systems designs have become stabilized, the summaries show clearly what further responsibility the Laboratory has for furnishing equipment of its own design. In short, the Laboratory is attempting to insure that in the future all submarines will be equipped with carefully engineered integrated antenna systems. The preparation of antenna systems summaries has proved to be an important factor in this effort.



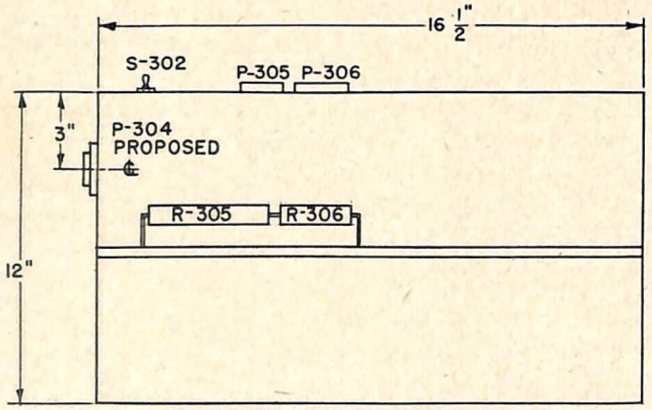
Outboard plan and profile of SSK1 Antenna Systems.



Outboard plan and profile of Guppy 1A Antenna Systems.

USING MODEL TCS with POWER SUPPLY PP-380/U

Remote control of the Model TCS radio equipment when used with Power Supply PP–380/U is made possible by means of a simple modification of the power supply to permit use with Remote Control NT–23270. This modification may be performed by Navy yard personnel using parts obtained from standard stock. No special tools are necessary. The modification consists of installing one 10-ampere 9-conductor plug connector, wall mounting type with mounting hardware manufactured by Cannon Electrical Development Company, Manufacturer's Type GK–9–32S on the chassis of Power Supply PP–380/U as shown in Figure 1. Using wire similar to NT SRIB–3 Standard Stock No. 15–C–4688–45, wire in the new connector as shown in Figure 2. Remove ground leads from switch S–602 and connector P–601 in remote control unit NT–23270 and connect S–602 and P–601 as shown in Figure 3. Removing the above leads from ground is necessary since relay K–302 in the power supply is actuated by 110 volts alternating current in lieu of 12.6 volts direct current as in previous power units used with the Model TCS equipments.



PP-380/U CHASSIS BOTTOM VIEW

FIGURE I

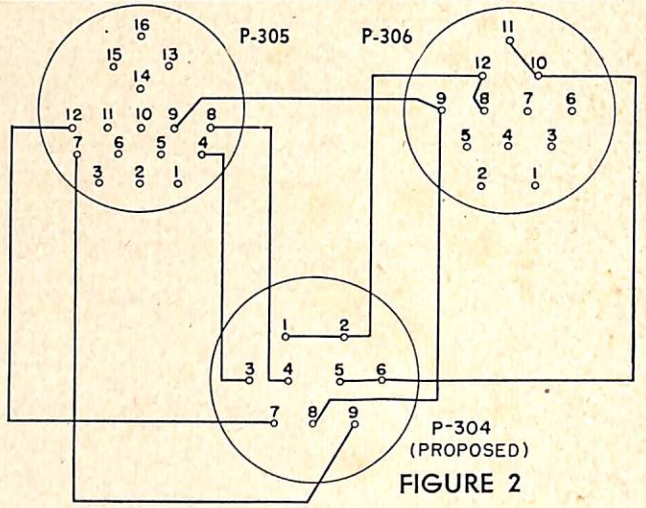


FIGURE 2

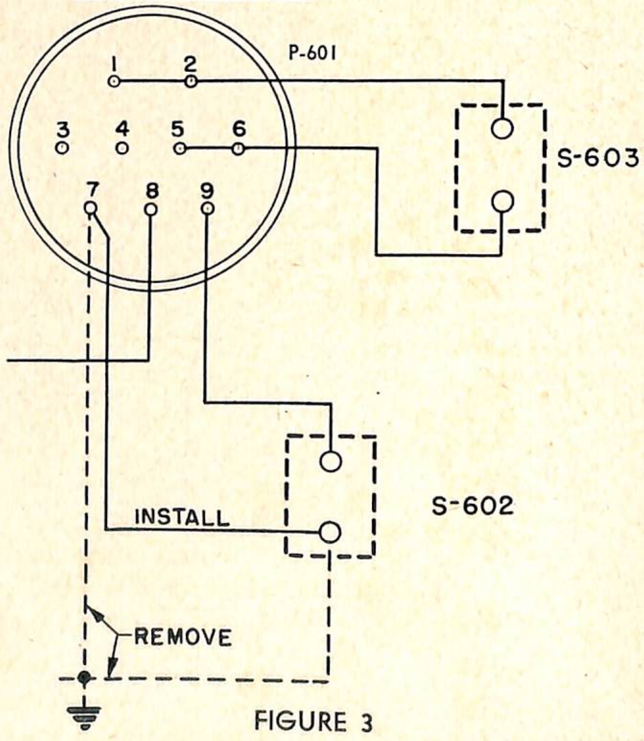


FIGURE 3

The modification above is to be on an optional basis and no kits are to be supplied. This modification was suggested by Commander, Charleston Naval Shipyard.

SP ANTENNA TRAIN DIFFICULTIES

by

Lt. J. G. Arthur J. Morrow, USN
U.S.S. Toledo (CA–133)

A condition of slight hunting in train of the Model SP radar antenna was observed and no amount of adjusting of balance and gain controls in the stable element and the train amplifier would remedy the situation. This condition existed for several weeks until it was noticed that the antenna made loud noises intermittently when rotated. The train motor in the pedestal was removed and after dismantling, it was observed that the gear train was dry and rusting in spots. The antenna was rotated by hand to check the gear train and the oil pump. The oil pump did not pump oil, although the oil pump level was above full. The gear train made considerable noise due to the lack of lubrication. Occasionally the high speed gear would not mesh properly causing extremely loud noises and a catching of the gear train. The high speed gear was also observed to have movement laterally which may have caused the mis-meshing.

The gear train section was removed to the work shop for complete disassembly. The following defects were noted:

1—The piston of the oil pump had been bent causing it to stick tightly in its cylinder.

2—The cam nut on the end of the gear shaft that operates the oil pump piston was very badly dented and nicked which may have been caused by the bent piston. No foreign matter was found in the pump that could have caused the dented cam nut.

3—The four shaft ball bearings were rusty and there was considerable grit in the bearings.

4—The high speed gear ball bearing was very gritty and loose. The outside ball race could be moved laterally with respect to the inside ball race.

The following corrective action was taken:

1—The oil pump was replaced from spares.

2—The cam surface of the cam nut was filed down to a smooth surface and was replaced in the equipment.

3—The four shaft ball bearings were replaced from tender spares.

4—The high speed gear ball bearing was not replaced from spares because it could not be located in tender spares and it is not carried in equipment spares. However, the ball bearing was cleaned thoroughly with diesel oil and packed with a light grease before replacing it in the equipment.

After reassembly and testing it was noted that the slight antenna hunting had disappeared and that the antenna rotated with much less noise. However, it is felt that the antenna hunting will re-occur as the high speed gear ball bearing works out the light grease and continues to wear out more due to the lateral movement of the ball bearing. A replacement is on order and will be installed when it is received.

MAXIMUM USE OF NLM AND CI EQUIPMENT IN SUBMARINES

The Noise Level Monitor and Cavitation Indicator Equipment (Model OMA) is designed to perform two distinct and separate functions. It serves either as a Cavitation Indicator (CI) or as a Noise Level Monitor (NLM).

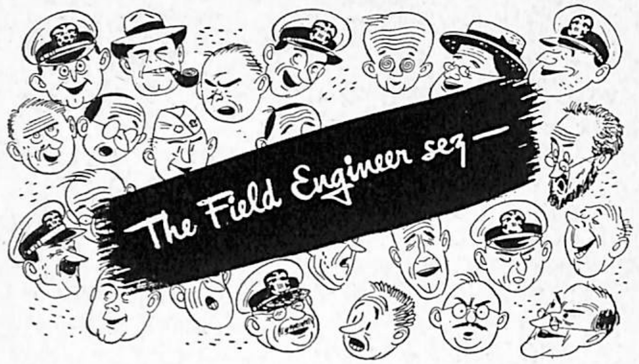
An accurate and rapid indication of own ship's cavitation or noise produced in the water by the vessel's screws at different underwater speeds may be obtained from the cavitation indicators, two of which are located in each vessel.

The Noise Level Monitor function of the equipment is designed to indicate noise transmitted into the water by the vessel's auxiliary machinery. The magnitude or average level of this noise at any instant can be read from the calibrated meter contained in the Navy Type –50310 amplifier.

The equipment is normally connected and set to perform as a Cavitation Indicator. In order to change over to the Noise Level Monitor, it is necessary to depress a spring-loaded switch on the amplifier unit of the equipment. Upon releasing the switch the equipment immediately returns to the cavitation indicator function. Provision is made for headphone monitoring of both functions.

Although of relatively simple design and construction, this equipment requires a thorough understanding of its performance and utilization. This is set forth in detail in the Model OMA Instruction Book, NavShips 91,027.

Since quick and accurate information as to own ship's machinery and screw noise and cavitation may be of vital importance during evasive action by submarines, it is apparent that this equipment, which is designed to indicate such potentially dangerous disturbances, should be given careful attention by all submarines of the fleet.



MARK 34 MODS 2 AND 6

Replacement of Gaskets on Cover Plates of Mark 63 Directors

It has been brought to our attention that considerable trouble in the Mark 34/2 radar is being caused by water getting into the Mark 63 director base. Resultant dampness of the internal and external leads (in cable twist) lowers their insulation resistance (in some cases as low as 0.1 megohm to ground) to such an extent that proper voltages are not delivered to the director T & E scopes. This is especially true in the case of the —472-volt lead. Without proper voltages, no spot will appear on the scope. This trouble can usually be cured by removing the two side plates from the director tube and allowing the leads to dry out. In most cases the presence of water is due to the poor condition of the rubber gaskets under the side plates. It is suggested that all ships carrying this type of director make a special effort to examine said gaskets and replace those which appear to be defective. W. S. McLean, *ComServLant.*

Adjustment of Potentiometers in Modulation Generator in Mark 34/2

Reports have been received from engineers that on several occasions equipments had been encountered wherein the factory-sealed potentiometers in the range unit had been tampered with. These equipments required resetting of all the controls in this unit. This process is time-consuming and requires detailed adjustments. Technicians are cautioned not to tamper with these factory-sealed potentiometers.—*Western Electric Newsletter.*

Some Mark 34/6 Equipments Shipped Without Instruction Books

Some early Mark 34/6 equipments were shipped without instruction books due to the fact that the books were not available at the time. Where the equipments were shipped direct to yards or installing activities, the books, and the supplements to the books, were shipped direct when available. Where the equipments were shipped to storage centers such as Mechanicsburg, Clearfield, and Lake Denmark, the books and supplements were shipped to the Supply Officer, Naval Supply Center, Norfolk 11, Virginia, marked for "Publication Supply Center". A total of 98 books with supplements were shipped to supply the 49 equipments shipped to storage less books. The serial numbers of the 49 equipments involved and the storage locations to which they were originally shipped are as follows:

Clearfield, Utah—1905 through 1909.
Lake Denmark, N. J.—1917 through 1924.
Mechanicsburg, Pa.—1910 through 1914, and 1934 through 1964.

Yards and ship activities having any of the above-listed equipments on board should requisition the instruction books and supplements for the subject equipments from the East Coast Publications Center, Norfolk, Virginia.—*Western Electric Newsletter.*

MARK 27 MOD 2

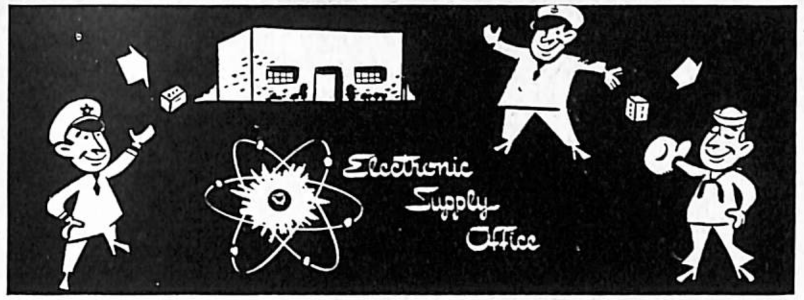
U.S.S. Newport News (CA–148)

The subject ship was in port for regular overhaul and an inspection of the Mark 27/2 Ser. 54 revealed that the range unit was so adjusted that the transmitter pulse was not gated at zero range and the range counter did not agree with the lower stop. Adjustments were made to the range unit using the clutch adjustment to bring the range step into agreement with the lower stop, and using the counter adjustment to give correct zero reading. The pre-knock adjustment in the transmitter-receiver was adjusted to bring the transmitter pulse into the gate at zero range.

This same trouble was found on the Mark 27/2 Ser. 53 and was corrected in a like manner. In addition, in the CW–55AAL–2 Range Indicator the range step on precision sweep was too far to the left. It was found that retardation coil, L1 in the step generator had changed value. This coil was replaced and the step returned to the center of the sweep, the normal condition.

In the Mark 27/2 Ser. 52 the range unit was so adjusted that the lower stop engaged at a range reading of 95,550 yards. In this position the transmitter pulse was not gated, nor was it gated at a range reading of approximately zero. The range potentiometer, R567, was checked and it was found that the arm of the potentiometer agreed with the position of the stops. By replacing V510 (6SN7) the range step was brought closer in agreement with the lower stop. By adjusting R587 and making use of the clutch adjustment the range step was brought into agreement with the lower stop. The range counter was charged to give a correct zero reading. Next, the pre-knock adjustment was used to move the transmitter pulse into the gate. It was also observed that there was no i-f gain. It was found that R40 in the CW–55AAL–2 Range Indicator was open, replacement of which corrected the trouble.

—R. F. Reynolds and L. C. Hubbard, Jr.



E.S.O. COLUMN MONTHLY

AMBER WIRE AVAILABLE

The Ships Supply Depot, Naval Supply Center, Norfolk, reports that it has approximately 1,200,000 feet of wire which is available to interested activities on a no cost basis.

This wire is in excellent condition except for the fact that it faded from its original yellow color coding to amber in random sections, and this precludes its utilization in circuit wiring where a specific yellow color is mandatory.

A description of the wire, ESO Stock Number N16–M–4409, which has successfully withstood a 1,000 VDC test in the activity's Electronic Laboratory, follows:

Wire, electrical, insulated; one conductor # 20 WAG; tinned copper, solid; white rayon woven insulation covered by yellow rayon, cellulose-acetate covering; insulation 500 VDCW, moisture-resistant; color-coded yellow.

CATALOGING POLICY

The following ESO Cataloging Policy has been established to assist in the proper integration and control of procurement and inventory of electronic maintenance repair parts in the Electronic Supply System. This will be accomplished by:

Naming, describing, numbering, and classifying each item required to maintain and effectively operate the Naval Electronic Spare Parts Program and which is procured, stocked and distributed by activities within the Electronic Supply System. Information covering each electronic item such as cross reference, numbering, supersedure and application will be complete, accurate and currently maintained on master records in the ESO. The characteristics for each item will be utilized to identify that item for all phases of supply. Data of this type required to facilitate procurement, identification, storage, issue, transfer and disposal of electronic maintenance repair parts by activities in the Electronic Supply System will be compiled and published on a continuing basis by ESO (or will be furnished by BuShips) in the form most effective for conveyance of the information. These catalog publications are distributed to Electronic Supply System activities and where necessary to other departments of the government and contractors as required by military necessity.

The publications are: (1) The Bureau of Ships Section, Part II (Electronics), Catalog of Navy Material; (2) Item Maintenance Lists; (3) Spare Parts Breakdown Lists; (4) Stock Number Status Bulletins; (5) Electronic Materials Cross Reference and Supplements; (6) Stock Number Description Cards; (7) Standard Price Lists and Supplements, and (8) Issue Precedence Lists.

MOTOR CONVERSION

Approximately 25 Teletype repair kits used in the conversion of Model 15 printers from series to synchronous motors are coming into the Electronic Supply System each month.

These kits consist of two principal parts and are being stocked by ESO. Because of the nature of the kit, it was determined that no single stock number should be assigned to the kit as a whole. Instead of ordering an entire kit, end users should requisition only those parts needed. When a complete kit is requested, this office will provide the major maintenance parts of which the kit is comprised:

Item	*Teletype Part No.*	*SNSN NUMBER*
a. Motor	MU–4	N17–T–350002–255
b. Gear Set	80437	F17–T–350001–103

ALNAV 56

The new procedure enunciated in ALNAV 56 is designed to expedite delivery of BuShips Controlled material to activities afloat and ashore.

This directive, which provides that an activity requisitioning such material forward a copy of its requisition to ESO, will accelerate the issuance of shipment orders as it enables ESO to take preliminary action on these items. This reduces the processing time inasmuch as the initial phases will have been completed by the time approval of the requisition is received from BuShips.

New Books

The following is a list of all instruction books distributed from 21 July 1950 to 8 December 1950. The most recent previous list of instruction books distributed appears in the October 1950 issue of BuShips Electron. The key to the abbreviations listed under the heading *"Edition"* appears below.

Supplementary lists will be published in BuShips Electron at regular intervals, as additional instruction books are distributed.

Abbreviation	*Edition*	*Abbreviation*	*Edition*
C	Commercial Publication	MI	Maintenance Instructions
Ch.	Change	OH	Operators' Handbook
CI	Complimentary Instructions	P	Preliminary Instruction Book
DB	Descriptive Booklet	RS	Revision Sheets
FC	Field Change	S	Supplement
IB	Instruction Book	SIG M-8	MarCor Parts List
IH	Installation Handbook	SP	Spare Parts Catalogue
IS	Instruction Sheets	T	Temporary
MH	Maintenance Handbook	TM	Technical Manual

Model	*Short Title*	*Edition*
AM–316/U, AM–317/U	NAVSHIPS 91347	IB
AN/AMT–8	NAVSHIPS 91367	IB
AN/FRT–6	NAVSHIPS 91263	IB
AN/GRQ–T1	NAVSHIPS 91336	IB
AN/MPN–1B	NAVSHIPS 98196	FC #12
AN/PDR–3A	—	SIG M–8
AN/PDR–8	NAVSHIPS 91221	IB
AN/PDR–8A	NAVSHIPS 91317	IB
AN/SLT–1	NAVSHIPS 91258	IB
AN/SLT–1	NAVSHIPS 91258.2	OH
AN/SLT–1	NAVSHIPS 91258.3	MH
AN/SLT–1	NAVSHIPS 91258.4	SP
AN/TPS–1B	NAVSHIPS 98178	FC #10
AN/UDR–6/–6A	NAVSHIPS 91028	IB
AN/UPA–T1	NAVSHIPS 91194	T–2
AN/UQC–1	NAVSHIPS 91180	T–2
AN/UQS–T1	NAVSHIPS 91274(A)	IB
AN/URA–6/–7, CV–57/URR	NAVSHIPS 91355	IB and T–1, T–2, T–3
AN/URA–8	NAVSHIPS 91339	IB
AN/URA–8A	NAVSHIPS 91278	IB
AN/URA–T2A	—	SIG M–8
AN/URC–3(XN–2)	NAVSHIPS 91359	CI
AN/URM–25	NAVSHIPS 91283	IB
AN/URM–4A	—	SIG M–8
AT–150/SRC, AS–390/SRC	NAVSHIPS 91338	IB
C–682/SR	NAVSHIPS 91307	IB
CAN–23550A, CAN 55223	NAVSHIPS 91358	T IB
CBOR–66134A	NAVSHIPS 91371	IB
CV–95/U	NAVSHIPS 91304	IB
DAU	—	SIG M–8
DT–20/UD	NAVSHIPS 91030	IB
HD–56/U	—	SIG M–8
IC/VRT–3	—	SIG M–8
IC405	—	SIG M–8
IE–12A	—	SIG M–8
IE–19	—	SIG M–8
KY–32/GRT	NAVSHIPS 91109	T–1
LAF	—	SIG M–8
LAJ	—	SIG M–8
LM	—	SIG M–8
MAR	NAVSHIPS 900,719(A)	IB
ME–6/U	—	SIG M–8
Mark 4	NAVSHIPS 91366	IB
Mark 4s	NAVSHIPS 91361	IB
MK 8 Mods 2 & 4	NAVSHIPS 98192	FC #5
MK 8 Mods 2 & 4	NAVSHIPS 900,967	T–1
MK–36/GR	—	SIG M–8
MX–561A/TPS–1B	—	SIG M–8
MX–803/UR	NAVSHIPS 91305	IB
MX–835/TPS–1B	NAVSHIPS 91250	IB
MX–835/TPS–1B	NAVSHIPS 91250	T–2
MX–904/U	—	SIG M–8
MX–1010/U	—	SIG M–8
NGA	NAVSHIPS 900,662	Ch 1
NGA–1	NAVSHIPS 91048	Ch 1
NGA–1	NAVSHIPS 98079	FC #1
NMC–2a	NAVSHIPS 91332	CI
OBL	—	SIG M–8
OBQ	—	SIG M–8
OC–1A/S, OC–2A/S and OC–3A/S	NAVSHIPS 91340	IB
OCJ–1	NAVSHIPS 91322(A)	IB
OCM	NAVSHIPS 91330	IB
OCM	—	SIG M–8
OKA	NAVSHIPS 98194	FC #4
OS–7/U	NAVSHIPS 91248	IB
OS–8/U	NAVSHIPS 91272	IB
PP–531/UR	NAVSHIPS 91374	IB
PP–531/UR	NAVSHIPS 91374	T–1
QDA	NAVSHIPS 98195	FC #4
QGA/–1	NAVSHIPS 91253	IB
QHB–1	NAVSHIPS 98197	FC #1
QHBa	NAVSHIPPS 98198	FC #1
RAO	—	SIG M–8
RAO–9	NAVSHIPS 98193	FC #1
RAO–9	NAVSHIPS 900,356	T–1
RBA–5a, RBB–2a, RBC–3a	NAVSHIPS 91319	CI
RBK	—	SIG M–8
RBL	—	SIG M–8
RBM	—	SIG M–8
RBS–2a	NAVSHIPS 91353	CI
RBW	—	SIG M–8
RBY	—	SIG M–8
RCX	—	SIG M–8
RD–49/U	NAVSHIPS 91365	CI
RDO	NAVSHIPS 98140	FC #2
RDO	NAVSHIPS 98134	FC #3
RDZ/–1	NAVSHIPS 91331	IB
REM	NAVSHIPS 91003(A)	Ch 1
RR–32/AM	NAVSHIPS 91352	CI
SA–197/TQM	NAVSHIPS 91323	IB
SCR–624	—	SIG M–8
SCR–634	—	SIG M–8
SG–1B	NAVSHIPS 98206	FC #60
SG–6	NAVSHIPS 900,861(A)	Ch 1
SG–6	NAVSHIPS 98190	FC #4
SG–18/U	—	SIG M–8
SR–6	NAVSHIPS 98183	FC #13
SR–6/–6B	NAVSHIPS 900,989	T–4
SS	NAVSHIPS 98075	FC #11
SS–1	NAVSHIPS 98281	IB
SS–1	NAVSHIPS 98281.2	OH
SS–1	NAVSHIPS 98281.3	MH
SS–1	NAVSHIPS 98281.4	SP
TCK	—	SIG M–8
TCM	—	SIG M–8
TDQ	—	SIG M–8
TDZ	NAVSHIPS 91328	IB
TE–11	—	SIG M–8
TE–21	—	SIG M–8
TEG–1	NAVSHIPS 91167	T–5
TEG–1	NAVSHIPS 91167	T–6
TS–230A/AP	NAVSHIPS 91105	IB
TS–230A/AP	NAVSHIPS 91105	Ch 1
TS–545/UP	NAVSHIPS 91213	Ch 1
TV–5/U	NAVSHIPS 91321	IB
UP	NAVSHIPS 98166	FC #2
V–35/U	NAVSHIPS 91306	OH
V–35/U	NAVSHIPS 91310	TM
VJ/–1	NAVSHIPS 900,829A	Ch 2
VK (X–VK)	NAVSHIPS 91377	Maint. Prints.
VK–2	—	SIG M–8
VL	NAVSHIPS 91177.2	OH
VL	NAVSHIPS 91177.4	SP
WFA–1a	NAVSHIPS 91286	IB
WFA–1a	NAVSHIPS 91286.2	OH
10351 (MX–907/U)	—	SIG M–8
10405	NAVSHIPS 91329	IB

MODIFICATION OF B & W ANTENNA CONNECTORS

Mr. Rowell A. Roberge and Mr. Jerome L. Messatzzia of the Long Beach Naval Shipyard submitted the following beneficial suggestion:

To prevent entrance of moisture in Barker and Williamson antenna connectors used at Naval Shore Radio Stations, modify the connector as follows:

1.—Before assembly of connector, drill and tap one side of connector for 45–F–365 (or equivalent) pressure type (Zerk) lubrication fitting. File lettering off connector as per sketch (Figure 1) to provide smooth seat for fitting.

2—Install fitting.

3—After assembly of connector, antenna, and coaxial cable, cover with "Dow-Corning No. 4 Dielectric Compound," ESO Stock N–16–C–12853–500. (ASO stock R52–C–3107–110).

Note: While this connector is slated for replacement by a redesigned unit, such replacement is in the future. It is recommended that this be used for new installations; also when connectors become available by lowering of existing antennas for maintenance, etc.

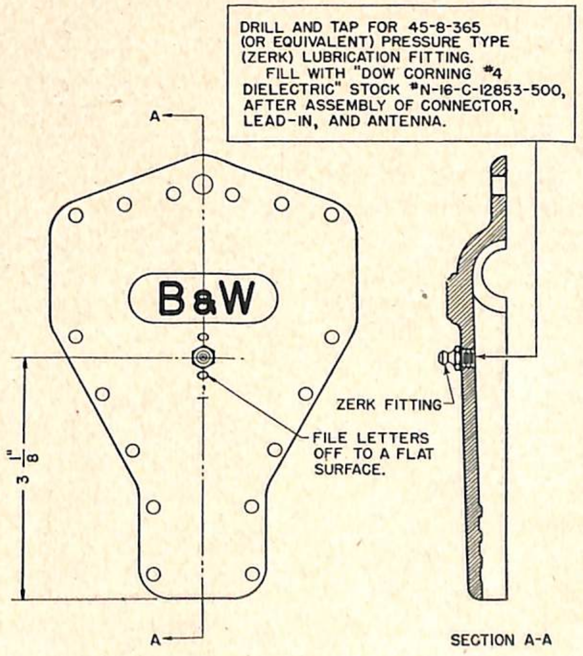


FIGURE 1

Table 3

Frequency response Western Electric Type 124 amplifier using Peerless Type 265Q output transformer. Resistors R18, R19, R12 and capacitors C7 and C11 are included in the circuit, but all other recommended circuit modifications are made. The load impedance is 4 ohms.

Frequency in cycles per second	Power output db (0 db is 12 watts)
20	1.0
50	0.5
200—8,000	0
16,000	— 1.0
20,000	— 2.0
25,000	— 3.0
30,,000	— 4.0
40,000	— 6.0
53,000	— 8.0
70,000	—10.0

As will be shown in Table 4 this choice gives flat response. For increase in treble response (as shown in Table 5) R29 is 820 ohms and C13 is 0.01 mf. In some drawings R4 is shown as 48,000 ohms.

To improve the bass response of the Type 142 amplifiers, the following circuit changes in the power supply are recommended by the Bell Telephone Laboratories: Replace R30 by a resistor having a resistance of 0.51 megohm. R30 is to be short-circuited when the amplifier is connected for 12 watts output. Connect the lead running to the mid point of the 80-mf filter condensers to the lower end of R25. Replace R26 by two resistors of 24,000 ohms each, or by a single resistor of 48,000 ohms.

The frequency response of the Western Electric Type 142 amplifier, when connected for 12 watts power output, is measured in exactly the same way as described for the Western Electric Type 124 amplifier.

The Western Electric Type 142 amplifier, when connected for 12 watts output and driven at 400 cycles per second will deliver 24 watts at 1% harmonic distortion.

Western Electric Type 143 Amplifier

Refer to BuShips Electron, May 1949, Page 18, Figure 15. To protect the amplifier under conditions of no load or very light load, the following circuit changes should be made: Connect a 0.047-mf condenser in parallel with a 10,000-ohm 2-watt resistor across Terminals 9 and 10 of Western Electric output transformer T–520A.

The writer found that the high frequency response of the amplifier may be considerably modified by connecting an 820-ohm resistor in series with a 0.01-mf capacitor from Pin 3 of V2 (½ 6SN7) to ground. This change in the circuit is not recommended. Tubes V2 and V3 should be carefully balanced. One effect of V3 unbalance is to unbalance the bias voltages on the output tubes. No distortion measurements are available.

Table 4

Frequency response Western Electric Type 142 amplifier, with recommended circuit modifications. R29 is 1000 ohms and C13 is 0.002 mf. The load impedance is 4 ohms. Waveform is excellent.

Frequency in cycles per second	Power output db (0 db is 12 watts)
20	— 1.0
40	— 0.5
100	— 0.1
200—1,000	0
2,000	0.5
4,000	0.5
13,000	0
20,000	0
26,000	— 1.0
40,000	— 2.0
45,000	— 4.0
60,000	—10.0

Table 5

Frequency response Western Electric amplifier Type 142, with recommended circuit modifications. R29 is 820 ohms and C13 is 0.01 mf. The load impedance is 4 ohms. Waveform is excellent.

Frequency in cycles per second	Power output db (0 db is 12 watts)
20	— 1.0
40	— 0.5
100	— 0.1
200—1,000	0
2,000	+ 1.0
4,000	+ 3.0
8,000	+ 4.0
14,000	+ 3.0
20,000	+ 1.0
22,000	0
25,000	— 1.0
30,000	— 3.0
45,000	— 7.0

Western Electric Speaker Type 757A—Circuit Modifications

Refer to BuShips Electron, May 1949, Page 8, Figure 2. In order to provide approximately 2 db additional treble attenuation when a Western Electric 713C high frequency driver is used with the KS 12027 horn, and a Western Electric Type 728B is employed as the bass speaker in the W.E. 757A combination, the following changes should be made in the L-attenuator: Connect a resistor of 16 ohms across the high frequency speaker, and a 1-ohm resistor in series with the line going from the high frequency speaker to the junction of the 0.3 ohm and 6.0 ohm resistors. The sounds emanating from a machine gun or tap dancer contain frequencies in the vicinity of cross-over, i.e., 800 to 1,000 cycles per second. Such program material is very useful for phasing dual loudspeakers. The sectoral (or multicellular) horn is positioned to obtain no echo effect, i.e., the high frequency and low frequency speakers blend into one. Correct phasing is manifest by the loss of consciousness that two speakers are involved.

Table 6

Frequency response, Western Electric Type 143 amplifier with recommended circuit modifications. The load impedance is 4 ohms. Four type 5881 tubes are used in the output stage. The wave form is very good at 30 cycles per second for 25 watts output. The maximum power output without excessive distortion is 42.5 watts.

Frequency in cycles per second	Power output db (0 db is 36 watts)
38	— 1.0
50	— 0.5
200 to 7,500	0
12,000	+ 0.5
20,000	0
27,000	— 1.0
33,000	— 2.0
38,000	— 3.0
69,000	—10.0
125,000	—20.0

Table 7

Same as Table 6 except 0 db corresponds to 12 watts.

Frequency in cycles per second	Power output db (0 db is 12 watts)
20	— 1.0
40	— 0.5
200 to 6,000	0
9,000	+ 0.5
12,000	+ 1.0
16,000	+ 2.0
20,000	+ 3.0
27,000	+ 3.0
35,000	+ 2.0
40,000	+ 1.0
43,000	0
46,000	— 1.0
50,000	— 2.0
53,000	— 3.0
64,000	— 6.0
80,000	—10.0
150,000	—20.0
200,000	—25.0

The Williamson Amplifier

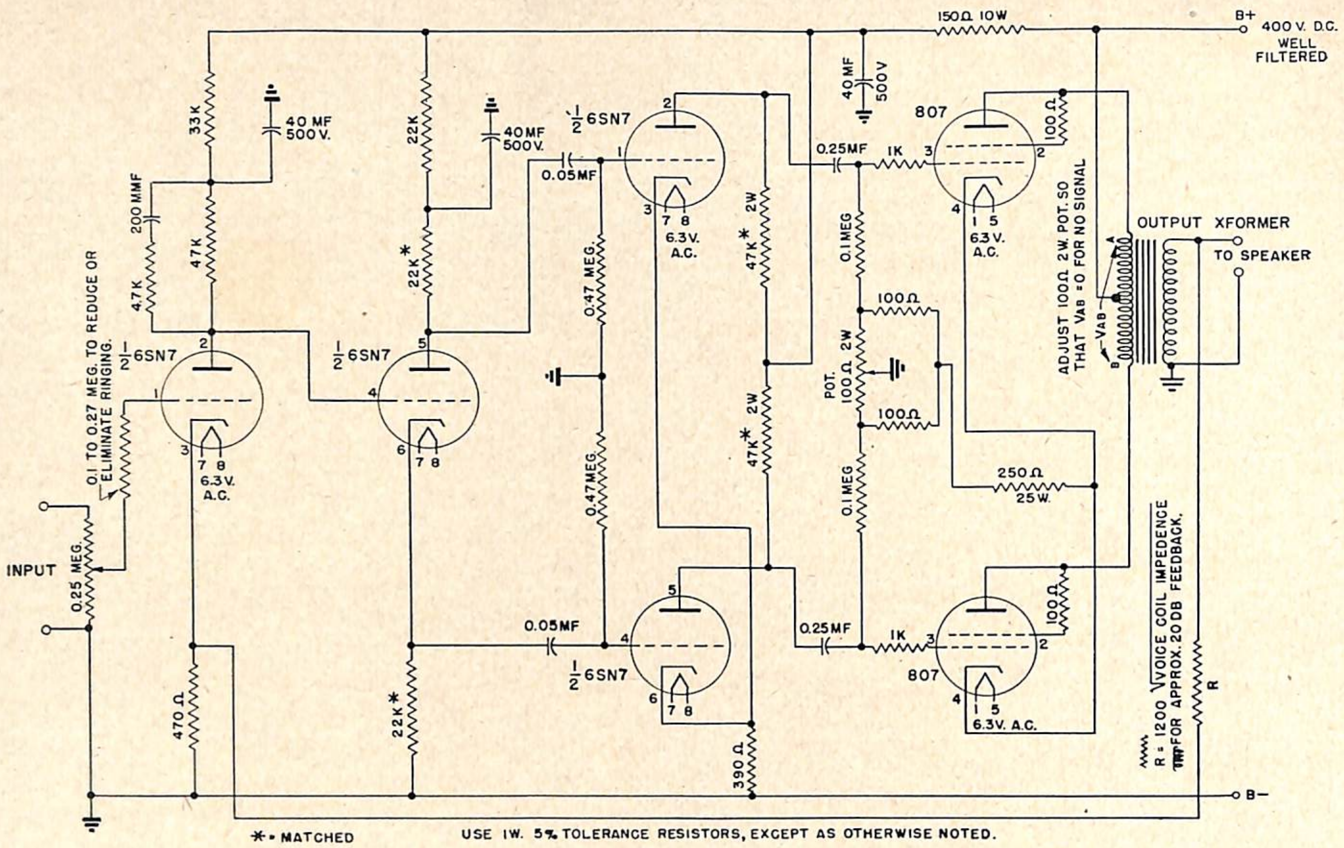
Figure 2 is a schematic wiring diagram of the Williamson amplifier—introduced in England. As usually built in this country two Type 6SN7 and two Type 807 tubes are employed. Feedback in the order of 20 db is used. For this condition

$$R = 1200\sqrt{\text{speaker voice coil impedance.}}$$

Observe that only four interstage coupling capacitors are employed in the circuit. Readers are cautioned not to attempt to build this circuit around just any available output transformer, for violent oscillations are sure to occur. To avoid instability the output transformer used must have an initial primary inductance of at least 100 H, and leakage inductance of not more than 33 mH. Subsonic oscillations are likely to occur if the initial primary inductance is not 100 H or more. When the feedback path includes the output transformer, and 20 db or more feedback is used, supersonic oscillations may occur if the leakage inductance exceeds 33 mH.

The writer has built two Williamson amplifiers. In one of these a Peerless Type 265Q output transformer is employed, and in the other a Partridge Type W.W.F.B. /0/1.7/ transformer, built to Williamson's specifications is used. When the amplifier is completed it should be checked for oscillation before the speaker is connected. If for example the feedback connection has been inadvertently reversed, the oscillatory power output of the amplifier may be sufficient to destroy the loudspeaker. Again if the amplifier oscillates and is not loaded by a resistance equal approximately to the voice coil impedance, the safe operating voltage of the output transformer may be exceeded, resulting in the loss of an expensive transformer. Conditions of stability should be checked using a germanium diode (such as the Sylvania 1N34) in series with a d-c meter across the voice coil winding of the output transformer.

Although the writer has a preference for the Western Electric series of amplifiers, the Williamson amplifier is an excellent one in many respects. Both amplifiers built by the author, when overloaded by a severe



*= MATCHED

USE 1W. 5% TOLERANCE RESISTORS, EXCEPT AS OTHERWISE NOTED.

FIGURE 2—Schematic wiring diagram of the Williamson amplifier.

transient signal generate violent subsonic oscillations of about 5 cycles per second periodicity. This phenomenon is readily observed by noting the large excursions of the bass speaker diaphragm.

When the amplifiers are checked using a square wave test signal having a period of 1/10,000 second (10 kc fundamental frequency), the output wave is found to be essentially square, but on its top (and bottom) appear a supersonic oscillation or ring. The oscillation is highly damped in the case of the amplifier using the Peerless output transformer, and extends only about one-third of the way across the top (and bottom) of the output square wave. When the amplifier using the Partridge transformer is tested under the same conditions, it is found that the supersonic oscillation is undamped and therefore extends all the way across the top (and bottom) of the output square wave. (See Figure 1.)

Ringing, as pointed out earlier in this article, is due to an attenuation characteristic which falls too rapidly in the high frequency region. It can be reduced or eliminated (at the expense of increased rise time) by installing a filter in the amplifier which provides a more gradual fall off in the high frequency response of the amplifier. Ringing was completely eliminated in the case of the Williamson amplifier, using the Peerless 265Q transformer, by installing a 0.27-megohm resistor in series with the grid of the input tube. It is well known that the input capacitance of a tube with a load in the plate circuit is different from its input capacitance with no plate load. The grid-to-cathode capacity of the first triode (½ 6SN7) is about 3 mmf. But with the plate load used in the Williamson amplifier the input capacitance is in the vicinity of 60 mmf. Thus the resistor and input capacity of the tube form the filter which eliminates, or substantially reduces ring in the Williamson amplifier. As shown by Figure 1 the Williamson amplifier, using the Peerless output transformer gives moderately good response to square waves of period 1/20 second. The amplifier using the Partridge transformer is phenomenal in this respect in that excellent response is obtained to square waves of period 1/5 second.

Frequency response data is taken on both Williamson amplifiers in the same way as for the Western Electric amplifiers previously considered. It is assumed that the rated power output of each amplifier is 12 watts, in order to correlate the results with the Western Electric 124 and 142 amplifiers. Except as specifically noted, the output wave form is not visibly distorted. No actual distortion measurements were made, but advertisers claim harmonic distortion is less than 0.25% at any frequency in the pass-band. This is an exaggerated claim (see Table 10).

Table 8

Frequency response of the Williamson amplifier, using Peerless 265Q output transformer. The load impedance is 4 ohms. An Allen-Bradley volume control (set wide open) of 0.25 megohm is used. Full power output is assumed to be 12 watts, with 18 db (measured) feedback. Noise level is —73 db (measured). A 0.27-megohm resistor is connected in series with the grid of the input tube.

Frequencies in cycles per second	Power output in watts (0 db is 12 watt level)
20 to 20,000	0
30,000	— 0.5
40,000	— 1.0
48,000	— 2.0
60,000	— 5.0
100,000	—10.0
130,000	—20.0
180,000	—30.0

Table 9

This table is identical to Table 8, except that the volume control is set to provide maximum frequency discrimination.

Frequencies in cycles per second	Power output in watts (0 db is 12 watt level)
20 to 10,000	0
20,000	— 0.5
30,000	— 1.5
35,000	— 2.0
41,000	— 3.0
50,000	— 5.0
90,000	—10.0

It is apparent, on comparing Tables 8 and 9, that an innocent looking high impedance volume control may have a profound effect on the high frequency response of an amplifier.

Transformer Characteristics

From a knowledge of the incremental primary inductance and leakage inductance of an output transformer it is possible to predict by a very simple calculation when the voltage response of the transformer will be down 3 db at each end of the pass band.

Table 10

Frequency response of the Williamson amplifier, using Partridge output transformer. Otherwise conditions are the same as in Table 8, except that no input filter is used, and the load impedance is 6.8 ohms.

Frequencies in cycles per second	Power output in watts (0 db is 12 watt level)	
20 to 50,000	0	The wave form is severely distorted in the region 45 to 60 kcs.
58,000	— 0.5	
68,000	— 2.0	
70,000	— 3.0	
80,000	— 5.0	
100,000	—14.0	

When the reactance of the primary winding is equal to the resistance formed by the load resistance referred to the primary side, and the tube a-c resistance (both taken plate-to-plate) in parallel, the output voltage will be 3 db below that at mid-range frequencies. Similarly at the high frequency end of the pass band the output voltage will be 3 db below that at mid range frequencies when the leakage reactance is equal to the sum of the load and tube a-c resistances (both taken plate-to-plate).

The Western Electric Type 171C transformer has a primary inductance of 44 H, and a leakage inductance of 57 mH, referred to the primary side. This value of leakage inductance is obtained when the 7.5-ohm winding is short-circuited. The reflected load resistance is 9,500 ohms plate-to-plate. Assume that the effective a-c resistance of a 6L6 tube is 2,500 ohms, or 5,000 ohms plate-to-plate. Then the parallel combination of the load and tube resistance is $\frac{5{,}000 \times 9{,}500}{5{,}000 + 9{,}500} = 3{,}270$ ohms. Since $2\pi fL = 3{,}270$, and $L = 44H$, $f = 11.85$ cycles per second. At this frequency the voltage response will be down 3 db, assuming other circuit characteristics of the amplifier are not controlling.

The series combination of the load and plate resistances is $5{,}000 + 9{,}500 = 14{,}500$ ohms. Then $2\pi fL = 14{,}500$ with $L = 57 \times 10^{-3}$ H. Therefore $f = 40{,}700$ cycles per second. At this frequency the voltage response will be down 3 db, assuming other circuit characteristics of the amplifier are not controlling.

The incremental primary inductance and leakage inductance are not the only properties of importance for output transformers used in push-pull circuits. Aside from the turns ratio, which is of evident importance for impedance matching, the incremental primary inductance as a function of d-c unbalance is a property worth consideration.

If the d-c resistance of the primary winding is high, power losses and harmonic distortion result.

A neat scheme for determining plate current balance is to connect a d-c voltmeter from anode-to-anode, under no signal conditions. If the meter reads zero the plate currents are balanced—provided the resistances of the two halves of the primary winding are equal.

In making the transformer measurements which follow, accepted laboratory procedures and techniques are used. All measurements of primary winding inductance are made using a line voltage of 60 cycles per second.

Western Electric Type 171C Transformer

This transformer has a primary winding d-c resistance of 221 ohms between Terminals 1 and 2, and 243 ohms between Terminals 2 and 3. The a-c primary balance is perfect. The reflected plate-to-plate load is 9,500 ohms (averaged for all output impedance combinations). The leakage inductance referred to the primary side is: measured across the primary with the various secondary windings shorted and is as follows:

Leakage Inductance mH	Secondary Winding Short-Circuited
59	1.75
57	7.5
69	16
56	30
80	150
76	600

The incremental primary inductance under conditions of no d-c unbalance lies between 41.5 H for 30 volts applied across the full primary winding, to 46 H for 120 volts applied. A 30-ma d-c unbalance causes the inductance of one half of the primary winding to drop less than 0.3 H—a phenomenon! This is true irrespective of the a-c voltage level used in the measurement.

It is seen that the Western Electric Type 171c transformer possesses two highly desirable characteristics:

1—The primary inductance is practically independent of the amplitude of voltage applied.

2—The primary inductance is essentially independent of d-c magnetization of the core.

Characteristic (1) infers that the frequency response of the amplifier using this transformer remains the same, whether it is operated at full power output, or at some level below full power output. The bass response of most ampifiers begins falling off as volume decreases, because the inductance of the primary winding is a pronounced function of drive voltage. Characteristic (2) infers that exact balancing of the plate current of the output tubes is not of great importance. However, harmonic distortion may increase rapidly with plate current unbalance.

Western Electric Type 519A Transformer

This transformer has a primary winding d-c resistance of 41 ohms between Terminals 11 and 12, and 55 ohms between Terminals 12 and 13. The a-c primary balance is perfect. The reflected plate-to-plate load is 6,100 ohms (averaged for all output impedance combinations). The leakage inductance referred to the primary side is:

Leakage Inductance mH	Secondary Winding Short-Circuited
11	400
9.3	200
24	24
26	12
26	8
32	4
28	2

If 100 volts a-c is impressed across the full primary winding, 12.8 volts appears across the feed-back winding. The turns ratio is thus 7.8 to 1, approximately. The incremental primary inductance under conditions of no d-c unbalance lies between 31.3 H for 10 volts applied to 78.8 H for 300 volts applied. A 10-ma d-c unbalance causes the inductance of one half of the primary winding to drop less than 4 H, irrespective of the a-c voltage level used in the measurement.

Western Electric Type 520A Transformer

This transformer has a primary winding d-c resistance of 10.3 ohms between Terminals 11 and 12, and 13 ohms between Terminals 12 and 13. There is a slight a-c primary unbalance. The reflected plate-to-plate load is 2,200 ohms (averaged for all output impedance combinations). The leakage inductance referred to the primary side is:

Leakage Inductance mH	Secondary Winding Short-Circuited
7	2
6.5	4
7.2	8
5.8	12
5.9	24
2.7	67
3.1	170

If 100 volts a-c is impressed across the full primary winding 16 volts appears across the feed-back winding. The turns ratio is thus 6.25 to 1, approximately. The incremental primary inductance under conditions of no d-c unbalance lies between 13 H for 10 volts a-c. applied to 23 H (maximum) for 150 volts a-c applied. A 20-ma d-c unbalance causes the inductance of one half of the primary winding to drop less than 0.88 H irrespective of the a-c voltage level used in the measurement. The incremental inductance of the first half of the primary winding is 5.7 H for 100 volts a-c applied, when no d-c is flowing in the second half of the primary winding.

Peerless Type 265Q Transformer

The d-c resistance of the primary winding of the transformer is 300 ohms, split into half-winding resistances of 145 and 155 ohms. The a-c primary balance is perfect. The reflected plate-to-plate load is 9,600 ohms (averaged for all output impedance combinations). The leakage inductance referred to the primary side is:

Leakage Inductance mH	Secondary Winding Short-Circuited
31	16
24	8
33	4
27	2

The incremental primary inductance under conditions of no d-c unbalance lies between 164 H for 10 volts applied, to 600 H for 300 volts applied. A 5-ma d-c unbalance causes the inductance of one half of the primary winding to drop 75 H, when the a-c voltage level used in the measurement is 150 volts. This transformer is thus very critical to d-c plate current unbalance.

Partridge Type W.W.F.B. /0/1.7/ Transformer (manufactured in England)

The d-c resistance balance is perfect, the total primary winding resistance being 440 ohms. The primary winding is perfectly balanced to a-c. The reflected plate-to-plate load is 10,000 ohms. The leakage inductance for the 6.8-ohm tap short-circuited is 18.2 mH, and for the 15.3-ohm tap short-circuited is 19.8 mH. The incremental primary inductance under conditions of no d-c unbalance lies between 117 H for 20 volts applied, to 444 H for 300 volts applied. A 5-ma d-c unbalance causes the inductance of one-half of the primary winding to drop 9H, when the a-c voltage level used in the measurement is 20 volts. This transformer is very sensitive to plate current unbalance.

Response of Magnetic Reproducers

Early in 1948 Mr. Weiant Wathen-Dunn of the Naval Research Laboratory made measurements of the frequency response of several magnetic reproducers. These data, which he has kindly consented to let the writer use, are presented in Figure 3. The Pickering, Clarkstan and General Electric pickups were selected at random.

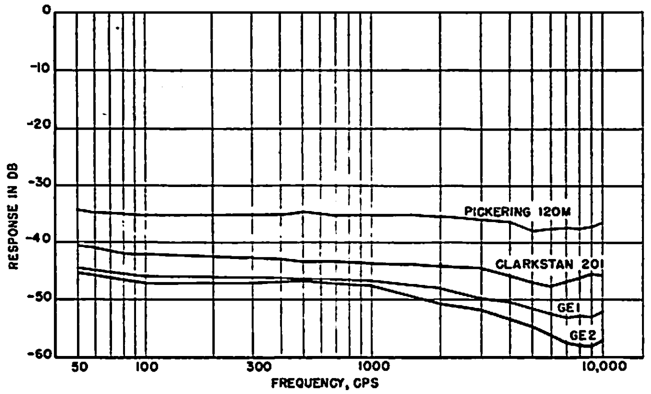


FIGURE 3—Curves for the response of the Pickering, Clarkstan and General Electric magnetic cartridge, as a function of frequency.

The db response of the reproducer, as plotted in Figure 3 is defined as $\text{db} = 20 \log_{10} \dfrac{E/V}{E_0/V_0}$.

Here E is the open-circuit voltage of the pickup, when the stylus is driven at velocity V. E_0 is taken as 1 volt, and V_0 as 1 inch per second. Under these circumstances the response of a cartridge may be defined as twenty times the common logarithm of the ratio between the open-circuit voltage generated by the reproducer, and the velocity of the stylus.

The frequency response measurements were made employing an optically calibrated test recording. The results, therefore, include the interaction of the stylus and record. This effect is not included when pickups are calibrated by use of a mechanical vibrator.

It is evident that the Pickering 120M cartridge not only possesses the smoothest response between 50 and 10,000 cycles per second, with the least high frequency roll off, but the greatest voltage output of any reproducer tested. If the superiority of the Pickering cartridge is maintained to both higher and lower frequencies, with gradual roll-off at each end of the pass-band, one can say that the transient response of the Pickering cartridge is better than the others, if the assumption is made that all cartridges are essentially distortionless. Distortion in pickups is defined as the generation of frequencies in the voltage output not present in the stylus actuating device.

The writer has obtained excellent results from the Pickering Type D–140S reproducer equipped with 0.001 inch radius diamond stylus for use with microgroove recordings. Unfortunately no calibration curves are available for this unit.

Resistance-Capacity Dividing Network For Two-Channel Power Amplifier

Mr. Irving Levine of the National Bureau of Standards kindly supplied the circuit diagram of the R-C dividing network employing cathode follower input and output stages, shown in Figure 4.

The dual channel amplifier has several advantages over a single amplifier for driving a dual loudspeaker. The use of a distortion producing dividing network at high signal levels is avoided as well as the power consuming attenuator in the high frequency channel. The divided transmission system permits exact impedance matching between amplifiers and speakers. For example, the amplifier handling the lower frequencies might be set up to drive a 16-ohm bass speaker and the amplifier handling the higher frequencies might be set up to drive a

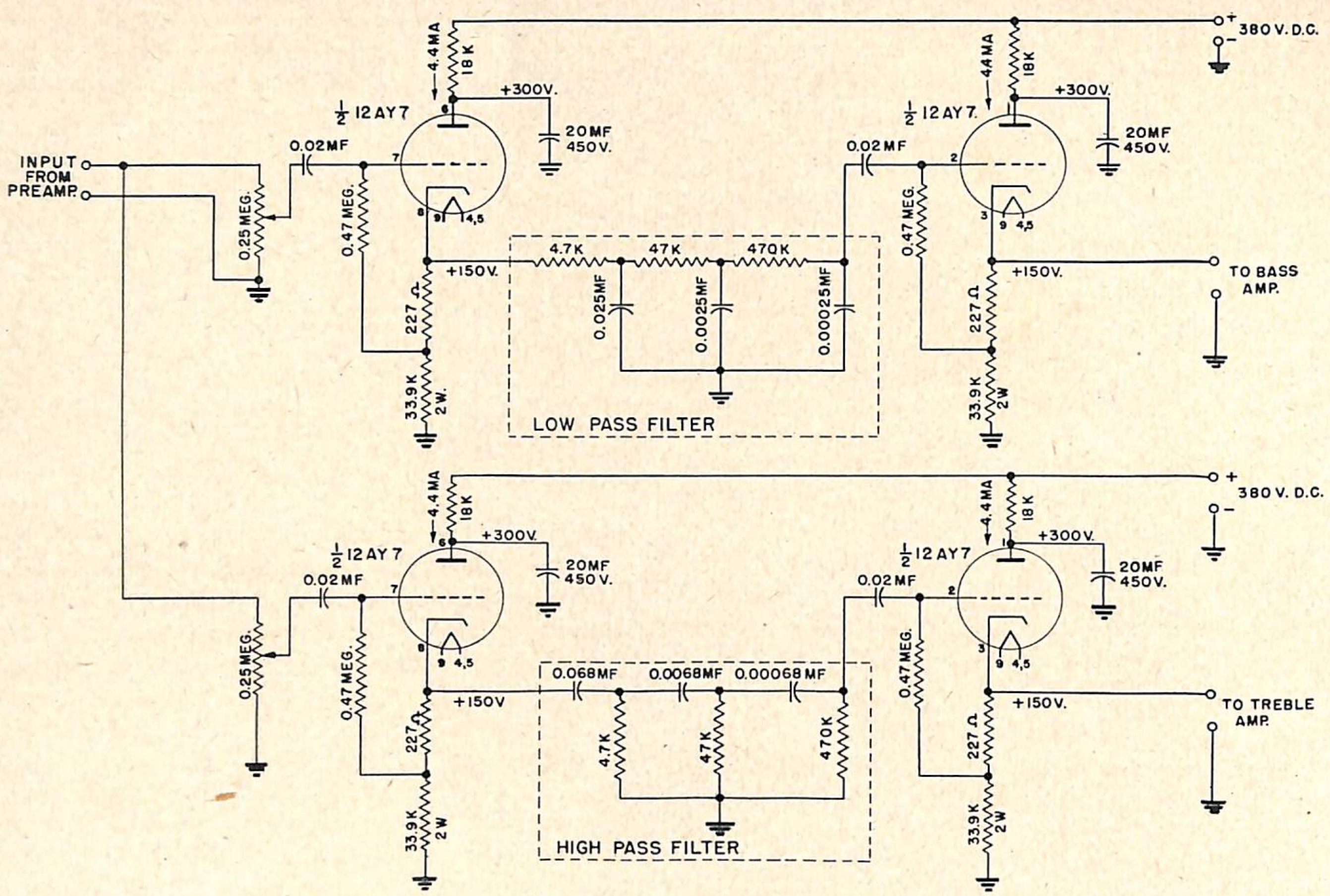


FIGURE 4—R-C dividing network.

high frequency receiver such as the Western Electric Type 594A loud speaking telephone having an impedance of 24 ohms.

Returning now to Figure 4, the high-pass and low-pass filters are included in dotted rectangles. The values of capacitors and resistors shown result in an 800 cycle per second cross-over. If, for example, a cross-over frequency of 500 cycles per second is desired, the values of the filter capacitors should be increased by the ratio 800/500. Each RC section should be adjusted until it is down 1 db at 800 cycles (for 800 cycles cross-over), so that the total attenuation for all three sections in cascade is 3 db at 800 cycles per second. The low frequency filter provides an attenuation approaching 18 db per octave above the cross-over frequency, and the high-frequency filter provides an attenuation approaching 18 db per octave below the cross-over frequency. The filters should not be loaded with a resistance of less than 5 megohms. As shown in the circuit they operate into cathode followers having input impedances of this order of magnitude. The filters could just as well operate into the grid circuits of tubes provided a proper dc- return is used in the grid circuit following the low-pass section.

The coupling capacitors of 0.02 mf used throughout the circuit are more than adequate from the point of view of low frequency response since the input impedance of each cathode follower approximates 5 megohms.

If desired the 0.25-megohm volume controls may be omitted, but the 0.02-mf capacitors must be used. It is not permissible to tie the grids of the input tubes directly together.

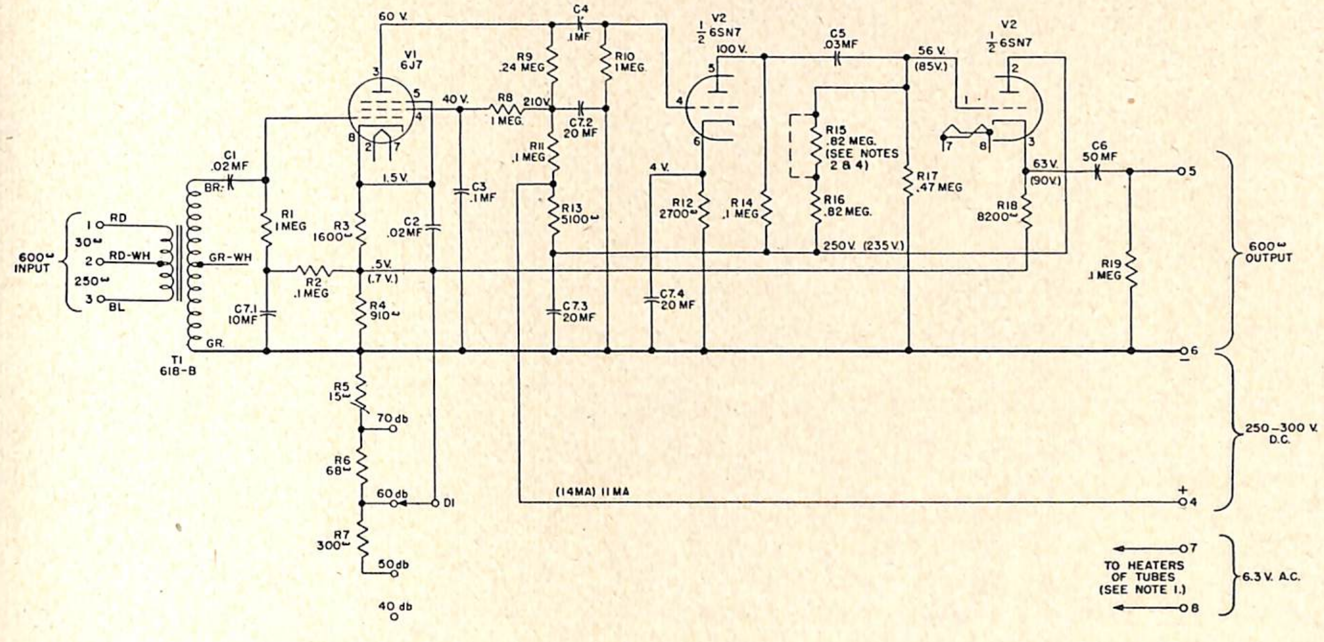
If the R-C dividing network and the dual channel amplifier are built on separate chassis, the output coupling capacitors (blocking capacitors) should be built into the dual channel amplifier. The connecting cables will thus be "hot" (+150 volts).

Output coupling capacitors of 0.1 mf may be used provided the grid resistors (or volume controls) employed in the input circuits of the dual channel amplifier are 0.25 megohm, or greater. Under these circumstances, equal voltages will appear across the coupling capacitor and grid resistor at about 6.4 cycles per second. At this frequency the voltage developed across the grid resistor will be 6 db down.

To prevent possible rupture of the diaphragm in the high frequency driver, the low frequency response of the associated amplifier should be limited. No attempt should be made to reduce the gain of a feedback amplifier at low frequencies by reducing the size of the interstage coupling capacitors, nor should a filter be used between the output transformer and high frequency receiver. One solution, affording some protection, is to reduce the value of the grid resistor in the input circuit of the high frequency amplifier, and reduce the value of the capacitor used between this amplifier and the high pass section of the R-C dividing network. As an example, assume that a grid resistor of 0.1 megohm is selected (so that the grid circuit is not too sensitive to hum pickup, etc., and the cathode follower is not too heavily loaded), and that 6 db attenuation is to be introduced at 159 cycles per second. The objective is to determine the required value of coupling capacitor. One has $C = 1/2\pi f R$ (f is the frequency). Thus $C = 1/2\pi\ (159)\ (100{,}000) \doteq 0.01$ mf. The fact that the response is down 6 db at 159 cycles per second does not have a deleterious effect at the cross-over frequency of 800 cycles per second. A simple calculation shows that for this choice of R and C in the coupling network the response is only 0.17 db down at 800 cycles per second.

Under these conditions if a loose connection develops between the high pass section of the dividing network and the high frequency amplifier, the diaphragm of the driver may not be destroyed. It is realized that this discussion on protective measures is by no means complete, and is included primarily to warn readers of the consequences of applying low frequency voltages to high frequency drivers.

The divided transmission scheme is a good way of achieving linear transmission of low frequencies (such as originate in drums, gun shots, explosions and thunder) together with linear transmission of high frequencies (such as originate in triangles, castanets, cymbals and tambourines), without severe modulation of the high frequencies by the low frequencies. It is to be noted, however, that use of a single amplifier having power output equal to the sum of the power outputs of the identical dual channel amplifiers will result in comparable performance provided all amplifiers possess the same distortion and frequency response characteristics. But it is generally impossible to obtain optimum generator impedance in driving the bass and treble speakers



NOTES:

1. FOR MINIMUM NOISE LEVEL, THE HEATER SUPPLY SHOULD BE BIASED ±15 TO ±45 VOLTS D.C. WITH RESPECT TO GROUND.

2. THE OUTPUT POWER VARIES WITH THE GAIN SETTING AND LOAD IMPEDANCE AND IS TABULATED BELOW FOR REPRESENTATIVE OPERATING CONDITIONS. THESE OUTPUT LEVELS ARE OBTAINED WITH NOT MORE THAN 1% TOTAL HARMONIC DISTORTION OVER THE FREQUENCY RANGE OF 50 TO 7500 CYCLES WHEN A 300 VOLT D.C. SUPPLY IS EMPLOYED.

GAIN CONTROL POSITION	CIRCUIT AS SUPPLIED	R15 SHORTED
	600 OHM LOAD	
40	+11	+14
50	+11	+14
60	+10	+13
70	+ 6	+11
	6000 OHM LOAD	
40	+17	+17
50	+17	+17
60	+17	+16
70	+15	+13

3. THE NUMBERS IN PARENTHESES ARE THE VOLTAGES AND CURRENT WITH R15 SHORTED.

4. IN CASES WHEN THE "B" SUPPLY VOLTAGE IS OTHER THAN 300 V., THE VOLTAGES INDICATED ARE MULTIPLIED BY THE RATIO OF THAT VOLTAGE TO 300.

5. THE VOLTAGES AND TOTAL CURRENT INDICATED REPRESENTS TYPICAL OPERATING CONDITIONS WITH AVERAGE TUBES, WITH A 300 V. D.C. "B" SUPPLY AND THE GAIN CONTROL AT 70db. THESE VOLTAGES SHOULD BE MEASURED WITH A VOLTMETER HAVING 11 MEGOHMS D.C. RESISTANCE. VOLTAGES ARE MEASURED FROM POINTS SHOWN TO TERMINAL 6 AND SHOULD BE WITHIN ±20%.

FIGURE 5—Western Electric Type 141A amplifier.

when a dividing network is interposed between an amplifier and dual loudspeaker.

Western Electric Type 141A Preamplifier

A schematic wiring diagram of the Western Electric Type 141A preamplifier suitable for use with a low impedance microphone is shown in Figure 5. This is not an equalizer-amplifier, the frequency response characteristic being essentially flat. If used with a magnetic pickup, an equalizer must be employed between the pickup and preamplifier. A very satisfactory equalizer for this purpose is the Pickering Model 163A.

The output of the amplifier is a cathode follower which will operate into load impedances of 600 ohms and up. It is especially suited for driving the amplifiers described in this and previous articles. One novel feature of the amplifier is the employment of an electrolytic output coupling capacitor of 50 mf, and the circuitry for accomplishing this.

Harmonic distortion under average conditions of operation will not exceed 0.3% over the pass band. The frequency response characteristic is flat from 50 to 15,000 cycles per second, falling off about 0.75 db at 20 and 20,000 cycles per second, when the Western Electric Type 618B input transformer is used.

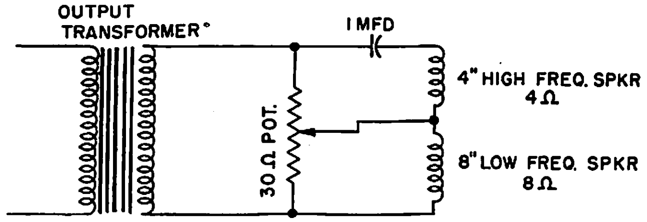


FIGURE 6—Subterfuge for a dual loudspeaker.

Subterfuge For a Dual Loudspeaker

A circuit diagram for a dual loudspeaker of some practical interest is shown in Figure 6. Here a 30-ohm power type potentiometer, and a 1-mf capacitor form the "dividing network." Two inexpensive speakers are used. A 12-inch speaker having an 8-ohm voice coil might be the woofer, and a 4-inch speaker having a 4-ohm voice coil might be the tweeter. The potentiometer permits pleasing high-to-low frequency balance to be obtained.

It is well known that most speakers do not respond to high frequencies because as the frequency of the driving voltage is increased their inductive reactance becomes so high that virtually no power can be delivered to them from the low impedance secondary winding of the output transformer. One method of achieving a more favorable impedance match at high frequencies is to "tune out" the inductive reactance of the speaker, by connecting a capacitor of suitable value in series with the speaker voice coil. Generally the resonance curve is fairly broad, so that very satisfactory results can be achieved in this way. It is surprising how good the 15-kc response of an ordinary 12-inch speaker can be, when resonated with a capacitor somewhere in the 10 to 15 kc region!

Requirements For a Good Sound System

The writer contends that a good sound system (including the loudspeaker) should pass square waves of period 1/15 to 1/7,500 second without noticeable distortion, i.e., change in wave shape. Square wave tests make sense when they are applied to a complete sound system. The proponents of square wave tests—particularly those in the audio equipment manufacturing business—should develop speakers and microphones which pass square waves! But until the advent of the speaker, microphone and phonograph pickup having good square wave response, one must be satisfied with inferior equipment. This is not to say that the writer feels that it is useless to possess a basic amplifier having good square wave pass qualities. A chain might as well have some strong links, even if it is inevitable that some weak links must exist.

Some workers in the field of audio engineering state that an amplifier should possess excellent amplitude response a decade below the lowest frequency in the pass band, and a decade above the highest frequency in the pass band to reduce modulation products within the range used and to minimize phase and transient effects within that range. If the band width required is 30 to 15,000 cycles per second, the frequency response characteristic would then have to be good from 3 to 150,000 cycles per second!

The writer is of the opinion that a flat frequency response characteristic an octave below and an actave above the frequency band of interest with gradual roll off in response at each end, will result in satisfactory phase and transient response. Then if harmonic distortion is limited to a fraction of 1% for normal operating level over the entire region of flat frequency response, intermodulation products within the frequency region of interest will be acceptably low. It is to be remembered that a step voltage, which bears some resemblance to certain musical notes, may be thought of as containing an infinite number of frequencies of finite voltage amplitude. Thus the complex sound wave emanating from a band, for example, may be resolved into a large number of sine wave signals of different periodicity and of discrete voltage amplitude. Some of these sinusoidal voltage waves are of frequencies above audibility. If harmonic distortion is not carefully controlled in the inaudible regions intermodulation products will exist in the audible frequency spectrum. In general, all of the amplifiers discussed in this and past articles are capable of excellent frequency response and low distortion over the frequency range 15 to 30,000 cycles per second, i.e., from an octave below to an octave above the band 30 to 15,000 cycles per second.

In a good sound system all elements of distortion should be minimized. This not only includes reduction of harmonic and intermodulation distortion—which are manifestations of the same phenomenon—but hum and noise as well. Intermodulation distortion should not exceed 4% which is another way of saying that harmonic distortion must not exceed 1% anywhere in the pass band. Noise and hum should be at least 70 db below full output level, i.e., the dynamic range (which is of great importance) should be at least 70 db.

The frequency response characteristic of a good amplifier should remain unaltered when the amplifier is operated at maximum level, and at 30 and 60 db below maximum level. The power handling capacity of the amplifier for sine wave voltage input should be at least 6 db beyond full modulation capacity over the entire signal band. Thus an amplifier which is to deliver 5 watts of power, for sine wave excitation, should have a power rating of at least 20 watts.

It is often brought out that the sounds emanating from a single musical instrument are usually harmonically related (this is true of string instruments, but not true for round drums, cymbals, etc.) and therefore sound system harmonic distortion which brings about changes in relative harmonic amplitudes is not too important. The same sound equipment when used to reproduce sounds originating in a group of sources may sound harsh, because of the intermodulating of the various frequencies involved. The way to lick this problem is to reduce harmonic distortion and thereby reduce intermodulation distortion!

It is of interest to observe that two amplifiers having the same overall harmonic content can and often do sound different, because low order or high order harmonic distortion can lead to the same overall harmonic content. Note also that the ear generates its own intermodulation distortion. If it didn't, it would be impossible to hear beats between two pure sounds of different frequency.

Summary

What this article has attempted to bring out, other than present some practical circuitry, is that a good amplifier has the following basic attributes:

1—The widest possible uniform frequency response characteristic with gradual roll off at each end.

2—The lowest possible harmonic distortion and noise level.

3—Unconditional stability.

Having achieved the desired amplifier frequency characteristic (including the frequency characteristic of the equalizer) the transient response is fixed. It is worth remembering that even though the transient response of a given amplifier may not be particularly good because of the frequency discrimination of the equalizer, if the equalization complements that which is used at the transmitting station, the transient response of the overall system, i.e., from microphone-to loudspeaker, (but not including these instruments) might turn out to be acceptably good provided the minimum phase shift criterion is satisfied.

Having determined the tolerable limit for harmonic distortion percentage, intermodulation distortion percentage is fixed and cannot be altered without altering the percentage of harmonic distortion.

Some persons have the mistaken notion that the application of feedback in an amplifier will correct for the deficiencies of the output transformer. The trouble with this theory is that the phase characteristic of a poor transformer is usually such as to prohibit application of sufficient feedback to correct for its deficiencies. Amplifier oscillation difficulties are sure to be encountered before the requisite band width and low harmonic distortion necessary to meet high fidelity requirements are achieved.

Don't be misled by anyone who says "you can't hear what goes on outside of the pass band so why worry?" Speech and music are transient in character, and the transient response in the pass band is a function of what happens outside of the pass band, as well as what happens within the pass band. Remember also that several signals that are inaudible can produce intermodulation products in the frequency band of interest.

Finally, don't waste money trying to build an equalizer having perfect transient response, and at the same time variable equalization! It cannot be done. Better to spend your money on a magnetic tape recorder, or if need be spend it on wine (coca cola), women (your wife) and song (listening to the Philadelphia Orchestra, in person).

MODEL SV WARNING

The item on Page 21 of the November ELECTRON concerning checking ON-TIME current in the Model SV radar implies that the procedure described could be employed by all hands. This is not the case—this procedure can be employed only by W.E. Field Engineers. If a technician must check this circuit, he is cautioned to abide by all Navy Department approved safety precautions, measuring the resistor in question with a resistance bridge and with the equipment OFF.

Letters to the Editor

Continuing a new, and it is sincerely hoped, a permanent feature of your magazine—ELECTRON. This new feature is the answer to numerous suggestions and requests from fleet and shore personnel for a medium of presenting their individual problems, gripes and questions on electronics matters and obtaining answers to such queries. This section is not to be confused with the FORUM which has been a regular part of the ELECTRON since its inception in 1945. The continuance of this new feature depends entirely on you—the personnel in the field—since we must first receive correspondence from the field before we can search out the answers and print them. As a matter of convenience, it is suggested you write directly to:

The Editor
BuShips Electron
Code 993
Bureau of Ships
Navy Department
Washington 25, D. C.

The following is typical of the type of letters received to date for inclusion in this column:

Editor
BUSHIPS ELECTRON
Sir:

I would like to know if the Sonar Monthly Performance and Operational Reports submitted by this ship are reaching the proper destination in the Bureau of Ships, if the form used is adequate and if the information is adequate.

E.A.W. SO1

To answer your questions:

1. These monthly reports are reaching their destination.

2. The form is not adequate. The Bureau is revising the form now and the new one should be available sometime in February. Each ship will be instructed how and when to request a new form from the District Printing and Publication Offices.

3. The information supplied is in some instances adequate, but, in general, it is not. This is the main reason the decision was reached to revise the forms. The new forms, if properly filled out, should supply all needed information.

When these reports are received in the Bureau of Ships mail room, they are routed to the cognizant engineer in charge of the particular equipment in the Installation and Maintenance Engineering Section of the Electronics Divisions, Bureau of Ships. The information contained in the report is recorded by ship, equipment, period, date, performance and operational difficulties. If serious difficulties are evident, previous report records are examined and analyzed. The results of this analysis are then the basis for Bureau action which may be a letter to the ship, an article in the Electronics Installation Bulletin, an article in BUSHIPS ELECTRON, *or the issuing of a field change to the equipment.*

One report alone is not necessarily of much value, but remember that every other ship in the Navy is submitting similar reports, and over a period of six months or a year, this wealth of information becomes a very valuable tool to the Bureau.

Your concern and interest as to the adequacy of the information received is commendable. Undoubtedly there are many hundreds more of you fellows with the same thought, "Is this just some more red tape that serves no useful purpose?" These monthly reports are a vital source of information. They are studied and acted upon; however, by the time the action is evident to you, due to unavoidable delay, it may have appeared that the information was ignored.

Editor

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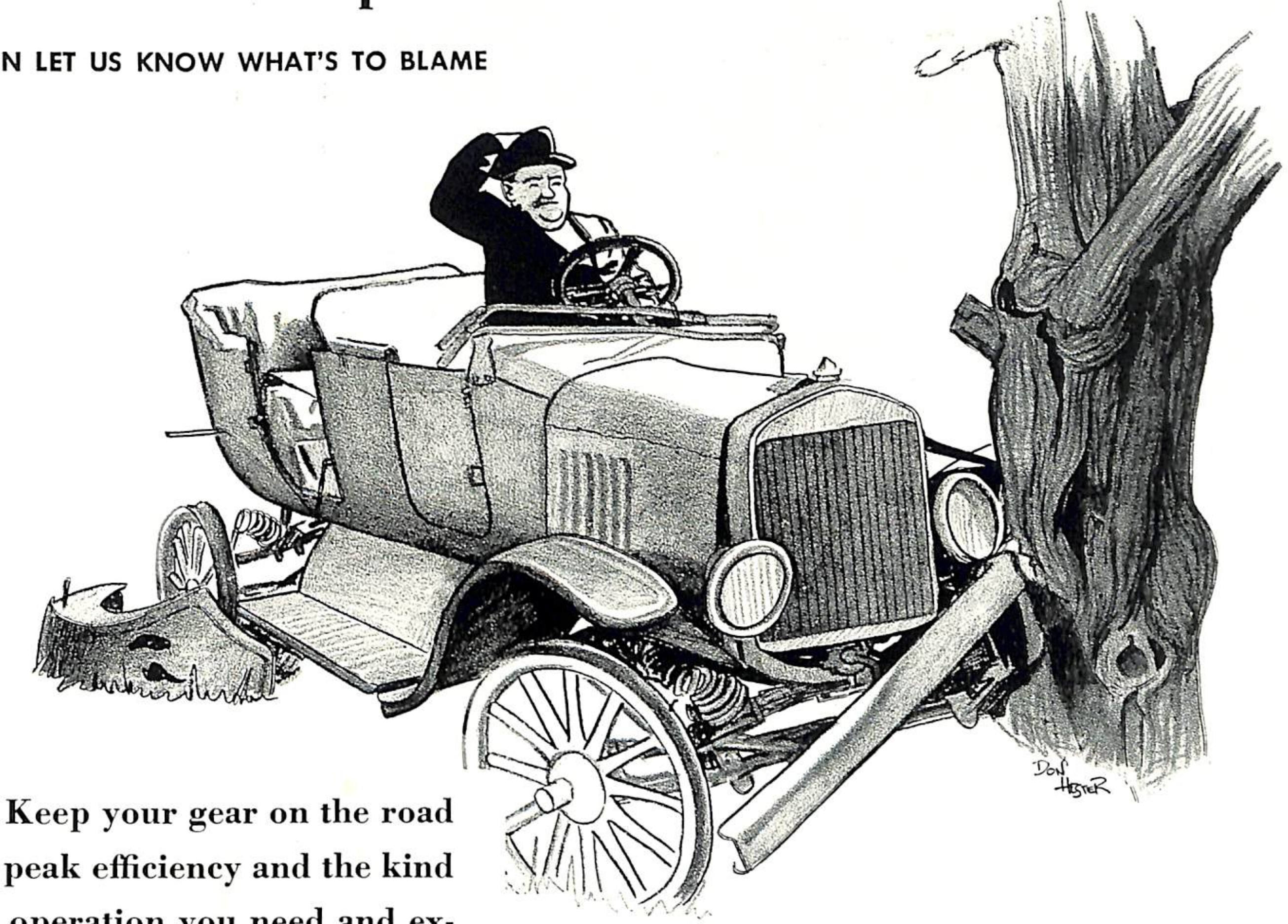
got a FAILURE to report ?

. . .THEN LET US KNOW WHAT'S TO BLAME



Keep your gear on the road to peak efficiency and the kind of operation you need and expect. If your chassis makes funny noises, overheats or won't make any noise at all, tell us how it failed. We need your help so we can make the next one better, and help you to keep it running smoothly.

SEND NAVSHIPS 383

TO CODE 962, BUREAU OF SHIPS
NAVY DEPARTMENT WASH. D.C.

THE FLEET SPEAKS

A SPECIAL ISSUE

. . . and it is up to you to make that speech an epic of straight facts. The September 1951 ELECTRON is being devoted entirely to you, the personnel of the Fleet. Every word will be written by and for sea-going officers and technicians. If you're tired of "sea horses", let's hear what you have to say.

Take your cue from the man at the right working hard scrambling vowels, consonants and verbs to tell his story to others throughout our Fleet. Send it to the Editor, BuShips ELECTRON.