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POWER PEAKER

a 200-watt output linear amplifier for single sideband.

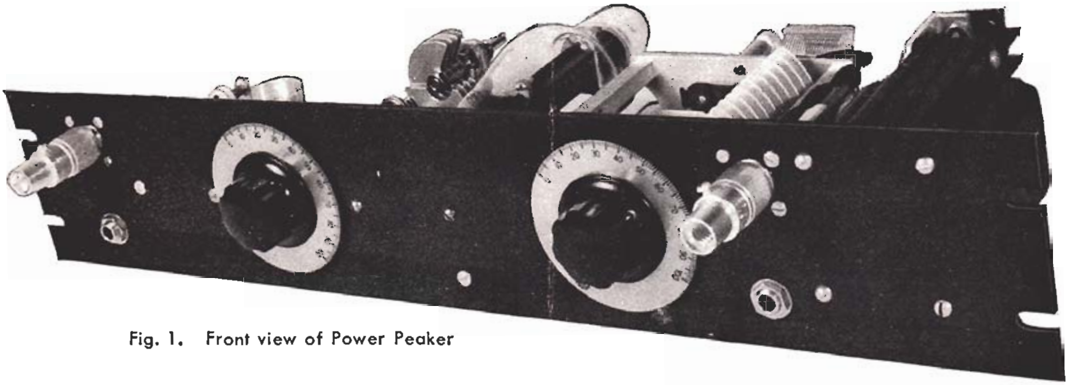

Fig. 1. Front view of Power Peaker

The Power Peaker is a complete single-tube linear amplifier featuring compact design for relay rack mounting. The r.f. driving power, for full 200-watt peak output, is less than 5 watts on any band from 80 meters to 10 meters. Thus, use of the Power Peaker driven by a single-sideband exciter, such as the SSB, JR (G-E HAM NEWS, VOL. 5 NO. 6), allows the single-sideband enthusiast to increase power by approximately 20 db. Two hundred watts of single-sideband is more than the communication equivalent of a half-kilowatt (plate input), high-level modulated AM rig operating at 80% efficiency. The Power Peaker will serve as an effective link between the 5-watt exciter and the antenna or a super-power (about 5 KW) final.

GENERAL DESCRIPTION

The Power Peaker amplifier is entirely self-contained (except for plate power supply) on a 3½ x 19 inch relay rack panel. All parts mount directly from the panel so that construction is easy and straightforward. The power amplifier tube is the rugged and dependable GL-811-A mounted horizontally near the center of the panel. Coaxial fittings are used for the r.f. input and output connections. Input and output tuning controls are accessible on the front panel as well as grid and cathode current jacks for circuit metering and tune-up. A filament transformer (T1) is mounted on the back of the panel to simplify the metering circuits and to avoid voltage drop in long filament leads.

Easily accessible plug-in coils are used for grid and plate circuits. Coupling adjustments may be made readily to match both input and output. These adjustments, once made for each band, "go with the coils" and need not be done again when changing bands. The neutralizing adjustment remains fixed from one band to another.

CIRCUIT DESIGN DETAILS

The circuit diagram of a linear amplifier is almost the same as that of a class "C" amplifier. Close inspection, however, will reveal an important difference between the Power Peaker and the conventional class "C" amplifier, that of bias. The GL-811-A is operated at zero bias and this feature makes additional swamping unnecessary. Actually this linear amplifier is self-swamped. Operating at zero bias reduces the driving power required, stabilizes the input impedance to reduce amplifier distortion, and, of course, eliminates the need for a bias supply.

The grid circuit is used as a phase inverter (accomplished with a split-stator tuning condenser) to per-

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mit grid-circuit neutralization. This arrangement reduces complexity and cost in the output circuit since it allows a single-unit plate tuning condenser to be used. The center tap of the grid coil is brought out to a grid-current jack (closed circuit type) through a 2.5 millihenry r.f. choke. The operating Q of the grid circuit is approximately 25.

The plate circuit is shunt-fed, thus reducing the insulation requirements on both the output tank coil and tuning condenser. Shock hazard is also reduced by this method. Economy of the design of the Power Peaker is exemplified by the use of small exciter-size plate tank coils. Although the amplifier will deliver a peak power output of 200 watts when loaded and driven properly, the small-size coils do not overheat. This, of course, is true because the average power of speech is small compared to peak power. The operating Q of the plate tank circuit is approximately 12 when the amplifier is loaded properly.

The over-all electrical design of the Power Peaker is aimed at economy, high efficiency (70% on peaks) and low distortion. Complete fulfillment of these design aims will not obtain, unless the coils and tuning condensers have respective inductances and capacities that are compatible with the original design. Because of the wide tuning range available, it is not sufficient just to use coils that will resonate at the desired frequency—they must resonate with the correct capacity for the frequency band in use.

It is strongly recommended that the Power Peaker be used ONLY with single-sideband suppressed carrier signals. The rating given is for this mode of operation only. More than momentary testing with continuous signals is almost certain to damage several of the components due to overheating. Keep this in mind.

CONSTRUCTIONAL DETAILS

The Power Peaker linear amplifier uses standard components throughout except for modification of the coils. This is necessary to obtain the required L/C ratios. Fig. 4 gives the layout of the 3½ x 19 inch (steel or aluminum) panel. Remember to reserve a clear space of at least one inch at each end of the panel for mounting on the rack. The plate tank condenser, C7, is spaced ½ inch from the panel by the three spacers furnished with the Hammarlund TC-220K condenser. Before mounting this component, scrape the paint from the rear of the panel under the spacers to assure good electrical connection. The socket for the plate tank coil, L4, is mounted on the end of the plate condenser, C7, with ¾-inch spacers, and oriented so that the axis of the coil is as shown in Fig. 3. The coil socket pins 1 and 6 should be toward the top of the panel. Ground pin 6 and use pin 1 for the adjustable tap connection. It will be necessary to drill and tap the back of the plate tank condenser in order to mount the coil socket. Be certain to use fiber washers next to the ceramic socket to prevent cracking as it is tightened.

The grid tuning condenser, C1, is mounted on the rear of the front panel after the paint is removed from the area immediately around the mounting hole. In general, be certain to do this for all grounded components. The National STN neutralizing condenser, C2, is mounted on a metal bracket ½ inch by 1⅝ inch long fastened to the rear of the grid tuning condenser, C1. The rear shaft bracket of the Hammarlund MCD-100M condenser already has two tapped holes (No. 4-40 thread) which can be used to mount the bracket. The stator plate of the STN condenser must be insulated from this bracket by means of the two stand-off insulators supplied with the condenser.

Electrical Circuit

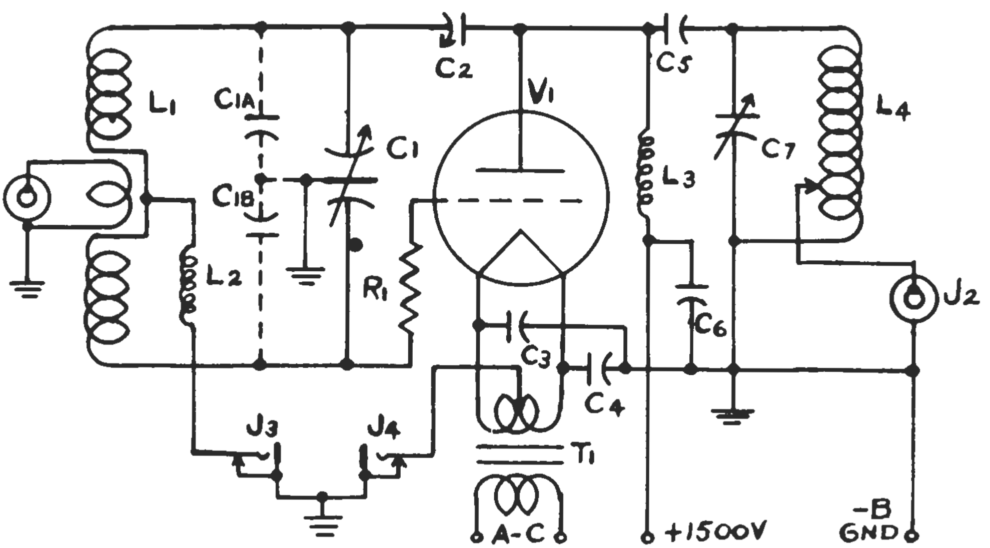

Fig. 2. Circuit diagram of Power Peaker

The tube socket should be spaced from the panel by two ¾-inch metal or ceramic spacers. The plane of pins 1 and 4 (filament pins) must be vertical as the panel is to be mounted. This is necessary to protect the tube from damage due to filament sag. The two 0.01 mfd ceramic disc filament by-pass condensers are mounted between the socket and the panel using shortest possible connections to a lug securely grounded. The plate supply by-pass condenser, C6, stands alongside the socket and one end is grounded to a lug fastened under the other socket spacer. The B plus end of the condenser is soldered to a lug mounted on a ceramic stand-off insulator. This point also serves to support the cold end of the National R-100, 2.5 millihenry shunt-feed r.f. choke. The plate blocking condenser, C5, is mounted between the stator lug of the plate tank condenser, C7, and the hot end of the shunt-feed choke, L3. A solid wire connects from this last-named point to the stator of the STN neutralizing condenser, C2. The objective here is to provide a rigid mounting for the blocking condenser, C5, and the top of the plate choke, L3, and to provide a connection point for the short insulated stranded-wire plate lead. The top of the blocking condenser, C5, should be below (toward the panel) the plane of the bottom of the plate of the tube to prevent interception of large amounts of heat radiated from the tube. A straight-across mounting of the blocking condenser should be about right, with due allowance made for inserting the GL-811-A. Fig. 3 shows these details clearly. A solid wire connection should be made from the same lug that mounts one end of the blocking condenser to the hot pin of the plate coil socket mounted on the end-plate of the tuning condenser. Use No. 14 AWG (or larger) for these solid-wire leads.

The filament transformer, T1, is mounted ½ inch from the panel on metal spacers to clear the leads which come out the bottom of the transformer. If the transformer you use does not have the leads coming out this way, it may be mounted flat against the panel. A terminal board is fastened to the top of the transformer by means of two right-angle metal brackets. This terminal board serves to connect the a-c supply and the 1500-volt d-c plate supply to the amplifier. A barrier-type terminal board is recommended for the sake of safety and to prevent inadvertent short circuits.

The center tap of the 6.3-volt winding of transformer T1 should be connected to the tip spring terminal of the closed-circuit cathode current jack, J4. Be certain to ground this jack securely to the metal panel. There is space on the panel below the transformer for a primary filament switch, if separate control of the filament is desired.

The ceramic socket, for the grid coil L1, is mounted on stand-off insulators so that the axis of the coil is vertical as shown in Fig. 3. The socket pins used for the swinging link should be toward the end of the panel for convenience in wiring and adjustment of the swinging link. The end connections (pins 2 and 5) of the grid tank coil should be connected with solid wire to the two stator sections of C1. The stator section away from the panel should be connected to the rotor of the STN neutralizing condenser. The stator section nearest the panel should connect to the grid pin of the GL-811-A socket (pin 3) through a 10-ohm, 1-watt non-inductive resistor (R1). This resistor is mounted by its pigtail leads between the stator connection and the socket terminal. The center tap of the grid coil (socket pin 4) should connect through a National R-100, 2.5 millihenry r.f. choke, (L2), to the tip connection of the closed-circuit grid current meter jack, J3. This choke may be supported by its pigtail leads from the socket connection and the jack terminal. Ground pin 3 of the grid coil socket to the panel with as short a lead as possible.

The filament wires may be twisted together and run between the plate condenser and the panel from the transformer to pins 1 and 4 of the GL-811-A socket. The B plus lead should run from the terminal board to the ceramic post supporting the shunt-feed r.f. choke. This lead should be kept clear of the stator connection of the plate tank condenser. Be certain to use wire with adequate insulation to withstand the 1500 volts.

CIRCUIT CONSTANTS

(All resistors and capacitors ±20% unless specified otherwise)

C1	*100-100 mmf variable condenser, Hammarlund MCD 100-M*
$C1_A$, $C1_B$	*See coil table*
C2	*3-18 mmf neutralizing condenser, National STN*
C3, C4	*0.01 mfd disk type ceramic condensers*
C5, C6	*0.001 mfd, 2500 volt mica condenser*
C7	*220 mmf variable condenser, Hammarlund TC-220K*
L1, L4	*National AR-17 coil, modified. See coil table*
L2, L3	*2.5 mh r.f. choke, National R-100*
R1	*10 ohm carbon, 1 watt resistor*
T1	*6.3 volt, 4 amp., ct, Stancor P4019 or equivalent*
J1, J2	*coax jack*
J3, J4	*Closed circuit phone jack*
V1	*GL-811-A tube*

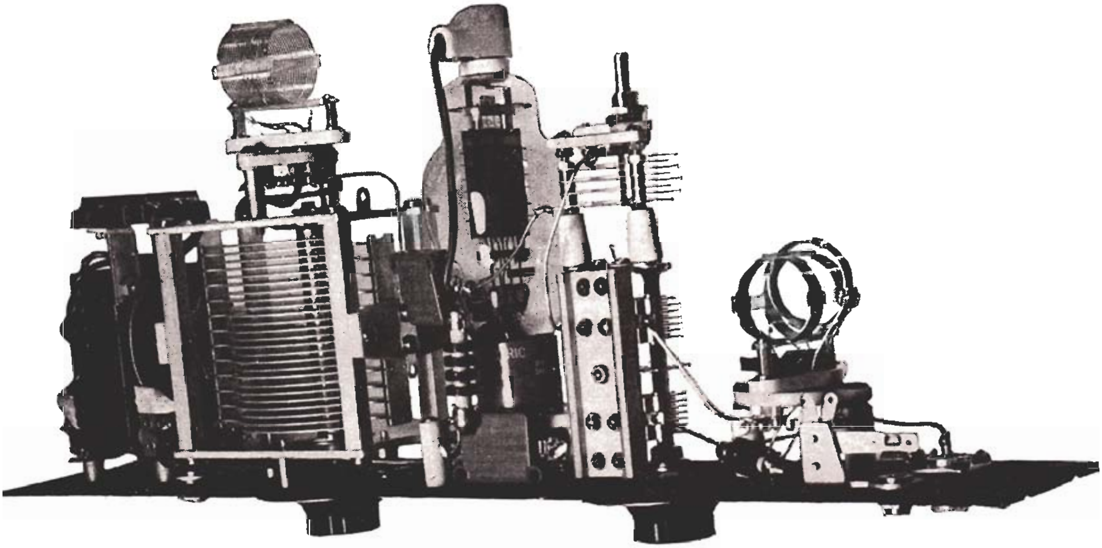

Fig. 3. Bottom view of Power Peaker

COIL DATA

It is essential to use coils having the correct inductance in order to meet the operating circuit Q's. The coils selected require modification in most cases in order to reach the required values. In addition, the two low-frequency-band grid coils require padding condensers mounted on the coil base as shown in Fig. 5.

Band	Coil	L μhy	Description
3.5–4.0	L4	10	National AR17-40E. Remove end link. Remove 8 turns. Provide 10 taps at ½ turn intervals from Pin No. 2 end. Connect Pin No. 6 to Pin No. 2 across top of coil base. Use a lead connected to Pin No. 1 for connection to taps.
	L1	14.5	National AR17-40S. Remove center tap of swinging link. Connect 150 mmf MICA condenser from each end of coil to Pin No. 3 of coil base. See Figs. 2 and 5.
7.0–7.3	L4	4.6	National AR17-20E. Remove end link. Tap each ¼ turn for 3 turns and make other connections as described for 3.5-4.0 MC plate coil.
	L1	7	National AR17-40S. Remove 3 turns from outer ends of each coil half. Remove center tap of swinging link from Pin No. 3 and connect a 50 mmf MICA condenser from each end of coil to Pin No. 3 of coil base. See Figs. 2 and 5.
14–14.4	L4	2.7	National AR17-20E. Remove end link. Remove 4 turns. Tap coil every ¼ turn for 3 turns and make other connections as described above for plate coils.
	L1	2.5	National AR17-20S—Remove CT from link.
21, 27–30	L4	0.9	National AR17-10E. Remove end link. Remove 2 turns. Tap each ⅛ turn for 2 turns and make other connections as described for plate coils.
	L1	1.2	National AR17-10S. Remove CT from link.

The inductance values for each coil are given for those who wish to make their own coils.

It might be necessary to remove some of the turns in the swinging links of the grid coils to facilitate matching the exciter into the Power Peaker. Do this if the exciter does not load properly when the link coil is fully meshed with the grid-tank coil.

POWER SUPPLY CONSIDERATIONS

A special word is in order concerning the plate power supply used with the Power Peaker linear amplifier. The L/C ratio chosen for the plate tank circuit is based on the use of a power-supply voltage of 1500 volts. Use of materially lower voltage (such as 1200 volts) will result in a loaded Q that is too low for proper operation of the amplifier when it is loaded as described under the section entitled MATCHING AND LOADING. A serious consequence of low output circuit Q is an abnormally high harmonic output. Thus, to develop rated output power while providing suitable load conditions for the amplifier tube, the power supply should deliver 1500 volts under load.

Good power-supply regulation is desirable for achievement of the best performance from any linear amplifier. A power supply that can deliver, say, 1500 volts at a load current of 200 ma, but which allows the voltage to rise to 1800 volts at the resting or static current of the Power Peaker amplifier will cause even the stand-by dissipation within the GL-811-A to exceed its rating—this will mean a short and unsatisfactory life for the tube. Design of a satisfactory power supply is discussed in G-E HAM NEWS, Vol. 7, No. 2 and THE RADIO AMATEUR'S HANDBOOK.

The type of load presented by a linear amplifier with single sideband input is identical to that of a class B modulator stage. To the information given in Vol. 7, No. 2 should be added that dynamic regulation of the power supply be considered also. Without going into details, one will end up with a really satisfactory plate power supply by following the design information given (especially with regard to input chokes, which affects "static" regulation) and then increasing the size of the output capacitor of the filter to a value considerably more than that required for satisfactory ripple performance.

Generally speaking, a power supply which has sufficient input choke to take care of static regulation needs only a single capacitor to meet the ripple requirement. This is provided the total value of capacitance is sufficient to iron out syllabic voltage fluctuations created by the intermittent load characteristic imposed by speech. At W2KUJ, where the Power Peaker was tested, an output capacitance of 25 mfd is used in the power supply to obtain good dynamic voltage regulation. An input choke of 60 henries is used to obtain good static regulation.

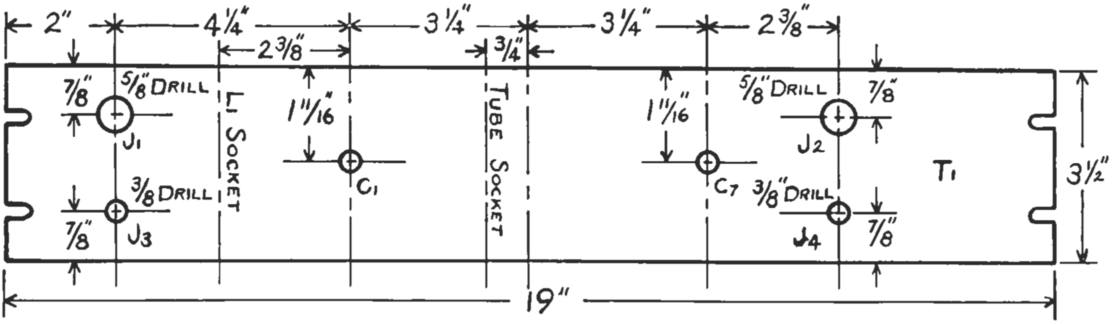

Fig. 4. Panel layout of the Power Peaker (Front Elevation)

Of course, transformer, rectifier tubes, and chokes of sufficient current rating (about 200 ma for the Power Peaker) and filter condensers of adequate voltage rating should be used.

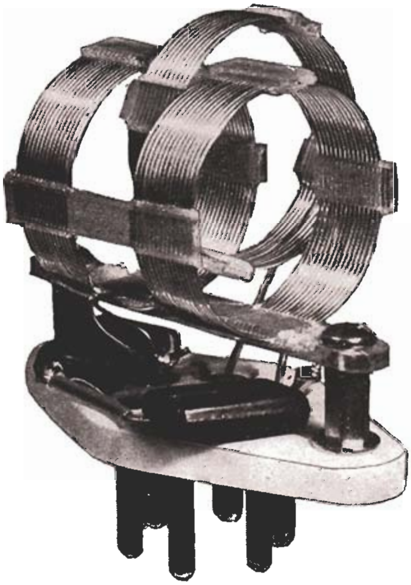

Fig. 5. Modification of grid tank coil

INITIAL TUNE-UP PROCEDURE

After checking the wiring and construction, apply power to the filament circuit. Insert the GL-811-A in its socket and connect the plate cap. Do not apply plate voltage—in fact, disconnect the plate power supply from the terminal board for the present. Plug in the set of coils covering the band you intend to operate and plug in a 0–50 ma meter in the grid current jack (J3). With power applied to the filament, it is normal to see about 2 or 3 ma grid current with *no* excitation.

Arrange to supply excitation to the amplifier at the desired frequency. Start with the center link loosely coupled and tune the grid circuit to resonance as indicated by maximum grid current. Set the neutralizing condenser about 90 degrees open and check grid circuit resonance. The amount of excitation used at this time is not critical—anywhere from 15 ma to 50 ma (maximum) will do. Adjust the coupling so that this order of magnitude is reached. If a single-sideband suppressed carrier exciter is used, it must be delivering some sort of a signal. A tone modulation, unbalanced carrier, or some reproducible signal will suffice.

NEUTRALIZATION

Disconnect the grid-current meter temporarily, but leave an open-circuited plug in the grid-current jack. Tune the plate tank circuit to resonance or near resonance as indicated by a lamp bulb connected to a loop of wire coupled to the plate coil, an oscilloscope connected to the output jack (use a one-turn tap on the coil) or any other neutralizing stunt you prefer. When fully neutralized, tuning the plate circuit through resonance will not affect the grid circuit. This may be verified by coupling the neutralizing indicator to the grid tank and tuning the plate circuit through its resonance point noted earlier.

With the amplifier neutralized, the plate supply may be connected, the grid-current meter reconnected, and a plate-current meter (0–250 ma) plugged into the cathode current jack (J4). With no excitation, the static plate current will be about 35 ma with 1500 volts applied. It will be noted that the static grid current will drop appreciably when plate voltage is applied. This is normal.

MATCHING AND LOADING

For further test, it is necessary to provide a load for the Power Peaker. Failure to do so will result in damaged coils. A dummy load which has the same resistance as your antenna is ideal for making coupling adjustments. Do not attempt to use incandescent lamp-bulb as a load because its resistance depends greatly on its temperature. An oscilloscope is also needed to check linearity and power when making a test with a two-tone signal. (See S. G. Reque, Linear R.F. Amplifiers, QST, May 1949, and R. W. Ehrlich, How To Test and Align a Linear Amplifier, QST, May 1952.)

Adjust the single-sideband exciter used as a driver for two-tone operation. Feed this signal into the input jack (J1), at a low level at first and connect the output link to a suitable load. Arrange the oscilloscope so that it can read the r.f. signal across the load. Enough signal will be available to see with the r.f. applied directly to the deflection plates. Apply plate voltage and resonate the grid tank (maximum grid current) and the plate tank (maximum load voltage) with fairly loose coupling to the output circuit.

(CAUTION—HIGH VOLTAGE! ALTHOUGH THE POWER PEAKER HAS BEEN DESIGNED WITH SAFETY IN MIND, IT IS WELL TO RECOGNIZE THE FACT THAT HIGH VOLTAGE IS USED AND THAT ALL "BACK OF THE PANEL" ADJUSTMENTS SHOULD BE MADE AFTER MAKING CERTAIN THAT THE HIGH-VOLTAGE SUPPLY IS NOT ONLY OFF BUT THAT THE FILTER CONDENSERS ARE DISCHARGED. WE DON'T WANT TO LOSE ANY OF OUR READERS JUST YET. STICK AROUND AND FIND OUT HOW WELL THE POWER PEAKER REALLY WORKS. 'NUFF SED?)

An arrangement should be made whereby the exciting signal can be turned off and on conveniently while making loading and matching adjustments. Do not run the test signal any longer at a time than is necessary to see the oscilloscope display and appraise it. Increase the input signal by either increasing the exciter output, or, the coupling in the grid circuit until the peaks of the two-tone output signal show definite flattening. Keeping the input signal at the level where flattening occurs, increase the coupling of the output by moving the tap up on L4 until the flattening disappears. Go a little further with this coupling. Next, increase the input signal until flattening again occurs and then increase the output coupling and so on. The tuning of plate and grid circuits should be checked for maximum output for each coupling adjustment made. You will note as the job progresses that the peak amplitude of the output signal keeps increasing. Along with this increased output you will note that the plate current has been increasing and so has the grid current. The stopping point is reached when either:

(a) The exciter can no longer deliver an undistorted two-tone signal, or,

(b) The plate current, with a two-tone test signal, has reached a value around 165 ma.

When condition (b) is reached, the tune-up procedure is completed, however, condition (a) requires an investigation of the exciter. Make certain that the Power Peaker is presenting a favorable load to the exciter. This is just a matter of juggling the coupling from the exciter and into the amplifier along with the exciter gain control if it has one. A peak driving power of about 2.5 watts is required, so if the exciter can deliver 5 watts peak power you have only to present the right load to the exciter.

The grid current under correctly loaded condition (b), will be somewhere around 20 ma with a total cathode current of 185 ma. Do not become concerned if the grid current is less than this amount, but if it is appreciably higher, increase the plate coupling or reduce the input signal or both.

If the procedure outlined has been followed carefully, the amplifier is loaded in an optimum manner. This may be checked by increasing the coupling to the output tank and noting the decrease in r.f. output signal (with fixed drive) and a slight decrease in grid current. Conversely, with fixed drive, decreasing the coupling from optimum will cause an increase in grid current and a flattening of the two-tone peaks as the signal passes through the amplifier. The plate current will drop. Bear in mind the objective is to load the amplifier for maximum output power for any given drive condition up to the maximum input current stated for condition (b). The objective is *not* to load the amplifier simply for maximum input, since the efficiency depends on the loading.

Although reading the tune-up procedure may raise several points not covered, remember that doing the job is probably not as bad as reading about it. The procedure is quite simple, as experience will show, and you will find that the description is quite detailed, perhaps needlessly so. Correct loading is essential to realize maximum output and efficiency together with low distortion.

OPERATING INFORMATION

Very little can be added here to what you already have learned in matching and loading the Power Peaker. Substitution of an antenna for the dummy load and a brief two-tone test with the oscilloscope as a monitor puts you on the air. Never try to exceed with speech signals the maximum peak level attained with the two-tone test. Not only will this fail, but also the quality of your single-sideband signal will be degraded. But worse than that, such practice destroys one of single-sideband's best points—a really narrow, minimum-interference, maximum intelligibility, signal. The Power Peaker linear amplifier can do a good job. Give it a chance and keep your sidebands clean.

Designer's CORNER

tank circuits Q's

We have mentioned at several places in the article on the Power Peaker something about tank circuit Q's, which possibly might have left some of our readers wondering what significance it all has in the design and operation of radio gear. The fact is that operating Q's have a very profound effect on the performance of most of the equipment we have, so a little working knowledge of the subject might serve as a useful guide in the selection of components and operating conditions in equipment we hams use every day. Do not blame us if you are moved to check into some of your gear after reading this discussion and make changes which improve the operation (more output, less TVI, cooler tubes, and the like) of equipment at your station.

The term "Q" is applied to the ratio of reactive power (wattless power) in a circuit to real power. From this basic definition of Q follows many interesting corollary relations in electrical circuits, although the concept is not in the least limited to the field of electricity. Immediately one can say that the Q of resistance is zero, and that the Q of a perfect coil or condenser is infinite. These are the absolute limits of Q's, but they are broad enough to provide plenty of room for error—or design, whichever way you may look at it.

What can a person do about Q if he buys a coil that has a Q of 250, and the designer of a circuit says such and so circuit should have a Q of 25? Are the manufacturers kidding; are they soaking us for a lot of Q we do not need; or does the designer of the circuit think that any old coil will do if it will fit into the coil socket? No, the manufacturer is talking about his *product* when he says its Q is 250; the designer is talking about his *circuit* which generally involves more than the coil alone, and he should know enough about it to pick components which are the right ones for the job. One of the fundamental properties of a coil of wire is its inductance. Disregarding distributed capacity (which can become a headache sometimes), the reactance of a coil is proportional to the product of its inductance and the frequency at which it is operated. Pure reactances are nice to talk about, but coils are not actually 100% pure reactances by the time you buy or make one—the wire has resistance! This resistance is generally distributed throughout the coil, as is the reactance, but let us think of it as being all drained down to the bottom of the coil in one chunk of pure resistance, leaving pure reactance at the top. If the reactance portion of this *series* circuit of pure reactance and pure resistance has a value of 250 ohms, and the resistance is one ohm, the Q of the coil is 250; or, concisely,

$$Q\ \text{coil} = \frac{\text{Reactance (X)}}{\text{Resistance (R)}} = \frac{250}{1} = 250.$$

This is consistent with the basic definition given earlier. What we have said about coils is equally true of capacitors, but it turns out that condensers can be made with much higher Q's than coils generally have, so we worry about coils a little more than capacitors when speaking about Q's of the circuit elements we use.

Well, if we apply 1000 volts RMS to this coil having a reactance of 250 ohms and a resistance of one ohm (the impedance is very, very nearly 250 ohms, not 251 ohms), 4 amperes of current will flow through both reactance and resistance, and the *real* power in the coil is 16 watts (which shows up as heat) and the reactive power is 4000 volt-amperes, so called to distinguish wattless power from real power. The heat generated in this transaction represents energy lost—or at least energy converted from electrical form (that can be used conveniently) into heat that warms the coil and does not ever show up as energy in the antenna. What of it? Why worry about 16 watts lost when we have 4000 volt-amperes reactive power in the coil? If volt-amperes were what we were after, this would be fine. Think of it—4000 volt-amperes that cost only 16 watts! A good bargain? Not bad if we know our P's (powers) and Q's, but that is the rest of the story. The circuit designer can now take over where the coil builder left off.

As we all know, a capacitor in parallel with a coil makes a tuned circuit. It turns out that at the resonant frequency of this circuit the reactance of the capacitor is equal to the reactance of the coil. If we tune our coil with a capacitor having a Q of 5000 (not unusual) we can truly neglect the 8/10 of a watt lost in the equivalent resistance of the capacitor compared with the 4000 volt-amperes of reactive power (not lost—yet) in the coil and capacitor, and the 16 watts loss in the coil. Now let us add a fourth circuit element to the reactance and resistance of the coil and the reactance of the capacitor comprising the tuned (tank) circuit we are talking about. Let us make this one a resistance, and let us put it across the condenser of the tank circuit. If 1000 volts is still supplied across the coil, it now appears across the resistance and the capacitor as well. A little over 16 watts has already been accounted for in the coil and condenser so what about the new resistor? Well, a current of E/R flows in it, and power *is* consumed in the resistance—no doubt about it. It is already pretty hot!

How much power goes into this resistor? That is an easy one. The power is

$$P\ \text{(watts)} = E^2/R = \frac{1{,}000{,}000}{R\ \text{(Ohms)}},$$ since the voltage E is 1000 volts, RMS, by hypothesis. If R is 5000 ohms, the power is 200 watts and the circuit Q is now

$$Q\ \text{(circuit)} = \frac{\text{Reactive Power}}{\text{Real Power}} = \frac{4000}{216} = 18.5$$ according to our basic definition of Q stated at the outset.

Let us not be quite so crude about it. Suppose the *equivalent* of this resistance is put across the capacitor by *coupling* a load to the coil and adjusting the coupling until the power delivered to the load is 200 watts. If the coupling job did not disturb the tuning, the circuit Q is still 18.5, and the generator feeding this circuit is unable to detect the difference. It still has to supply 216 real watts as before and 4000 volt-amperes to the coil and the capacitor of the tank circuit. In fact, the generator does not even feel the 4000 VA in the coil because the 4000 VA in the capacitor happens to cancel the reactive power of the coil! That is co-operation on a pretty big scale, but nobody should be surprised about it—this is what happens at resonance. Has the bargain evaporated? Not entirely, although the 4000 VA has slipped through our fingers somehow. Pfoof! That was wattless power anyway. We did get 200 watts of good output from our circuit that loaded the generator to 216 watts, so the circuit efficiency is

$$\eta\ \text{(circuit)} = \frac{200}{216} \times 100 = 92.6\%,$$ a pretty fair bargain at that. Had we loaded the circuit to extract only 100 watts, the circuit efficiency would have been 100/116 $\times 100 = 86.3\%$, not quite so good. The circuit Q in this case would have been 34.5. If the circuit were not loaded at all, the circuit efficiency would have been zero, with a Q of almost 250, about the same as that of the coil. Loading the circuit so that 400 watts is delivered would give a circuit efficiency of $100 \times \frac{400}{416} =$ 96.2% with a circuit Q of 9.62. Which loading would you choose? To answer that we must consider the characteristics of the generator and the signal it generates.

If the generator had sinusoidal waveform (no harmonics) the tank circuit would not be needed at all, and so the load circuit efficiency would be very close to 100% at any power level. But the generators we are interested in are vacuum tubes running as class B or C amplifiers, generally. A class B amplifier delivers a signal that is only half of a sine wave, and a class C amplifier does even less. The tank circuit helps the tube, which delivers only half of a sine wave (or less), to deliver a whole sine wave to the load. The degree to which this is done is almost directly proportional to the operating Q of the circuit. Thus, the tank circuit serves as a much needed coupling device between the tube and the load, and by various adjustments of coupling, we can make a fixed value of load resistance present a chosen value of load into which the tube (generator) actually delivers power. A little power loss in the tank circuit is justifiable, since we have limited control over the actual load resistance and the tube characteristics; i.e., the optimum load for the tube itself. We have seen that the power output of the generator depends on the load resistance presented to it, in this case across the capacitor of the tank circuit. For a given tube and mode of operation (class A, AB, B, or C) there is a definite best loading. Too light a load will not allow a reasonable output power; too heavy a load, on the other hand, wastes power in the tube (generator) and makes it overheat. All of these factors indicate a compromise, with the circuit designer as referee. It has been found that circuit Q's of about 10 or more make the tube happy—accept power for half a cycle or less and deliver power for a whole cycle. The numerical example showed us that the higher circuit Q's had lower efficiencies (with a fixed coil Q) so this tends to push the choice of circuit Q down.

The response of a tuned circuit to harmonics is approximately $\frac{1}{nQ}$, where n is the order of the harmonic (2 for second, 3 for third, etc.), so this consideration makes a choice of high Q desirable. A good all-round choice of operating Q is from 12 to 15, a compromise to be sure. Now we do some juggling. We want to present the optimum load to the tube, but we must keep it happy. We also want to have good discrimination against harmonics present in the output of the tube. In addition, we want to waste as little of the tube's output power as possible; that is, we want good over-all efficiency. Having chosen the operating voltage for the tube, the optimum resonant load resistance is fixed. Taking this and a value of circuit Q around 12 to 15 we can solve for the reactance of the coil and the condenser by substituting values in the following equation:

$$\text{Reactance} = \frac{\text{Load Resistance desired}}{\text{Q (circuit)}}$$

This is the value that must be used to obtain the desired output power at good tube efficiency, at reasonable circuit efficiency, and with reasonable harmonic attenuation. Circuit Q affects all these things. The Q of the coil alone determines the power loss in the coil, once its reactance is established. Doubling the Q of the coil alone will cut the power loss in the coil itself to half—a desirable move for the sake of the coil—but this is not so easy, and the circuit efficiency will be raised only a little bit (from 96%, say, to 98%, a little difficult to detect on the scale of the output power). Doubling the coil Q will not affect *in the least* the loss occurring in the tube itself. That loss is determined by the load into which the tube works, and by the mode of operation; i.e., class A, B, or C.

It takes no magician to apply the foregoing information intelligently. In the Power Peaker amplifier, for example, the output circuit Q was chosen at about 15. (This will vary somewhat throughout a given band because of tuning.) The choice of 1500 volts (the highest allowed by the tube manufacturer) was made to get the greatest useable output power, and this sets the value of load resistance and coil reactance at any operating frequency. The numbers used in the foregoing numerical examples are quite close to those actually appearing in the Power Peaker amplifier. That is all there was to it. Easy? You betcha!

One more comment. If a Q of 12 or 15 is so good for the output circuit why was a Q of 25 chosen for the input (grid circuit) of the Power Peaker? Two main considerations guided this choice. The input load of the GL811-A depends somewhat on the loading in the output circuit. In order to have some latitude for error, the Q of the input circuit was made higher than actually necessary so that things would be on the safe side. The other consideration was this: the exciter, when coupled to the amplifier grid circuit, lowers the grid-circuit Q. Thus, it is quite probable that the working Q of the grid tank circuit will be around 15, after all.

Watch your P's and Q's. Keep your tubes happy, get more power out of your rig, lower the harmonic output, and save money in the choice of suitable components.

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Be sure to see the G-E ad, Page one, October issue of QST and CQ, announcing the new G-E Amateur award. Complete details will also appear in the NOV.-DEC., VOL. 7, NO. 6 issue of HAM NEWS.

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