New High-Power Transmitting Pentode

200-Watt R.F. Output With Excitation Small

A BIG brother to the RK-20 has been added to the Raytheon transmitting line — a 2000-volt pentode which offers some real advantages for amateur transmitters of the higher-power classifications. The new tube, which will be known as the RK-28, is capable of outputs of the order of 250 watts for c.w. work, and can deliver 60 watts or better of 100%-modulated 'phone carrier, using suppressor-grid modulation. The characteristic pentode economy of excitation is present to the nth degree in the RK-28.

At this writing the power ratings on the tube are only tentative, pending completion of life tests at the factory. The power figures given below therefore are on the conservative side. The plate dissipation rating of 100 watts, for instance, is probably below the actual safe rating, since the plate is a good deal larger than in present tubes having 100-watt dissipation ratings. It is expected that production tubes will come through with a bulb of larger diameter than that shown in the photograph, at which time the size of the radiating fins on the plate will be increased so that the final plate dissipation rating may be in the neighborhood of 150 watts.

The internal structure of the tube resembles that of the RK-20, all elements of course being larger. The RK-28 has its plate brought out to a cap on top of the bulb, with the filament and grids connected to a 5-prong base at the opposite end. The base, of ceramic material, is an enlarged version of the familiar 5-prong receiving tube base, being about two inches in diameter and having much heavier pins. A new type of transmitting tube socket therefore will be needed for the tube; this, however, will mean no hardship except possibly temporarily, since several manufacturers expect to bring out suitable sockets in the near future. The overall length of the new tube is about half again as great as that of the ordinary "fifty-watter", with a bulb of larger diameter. Pin connections are the same as on the RK-20.

The RK-28 can be used for practically every type of r.f. service—crystal oscillator, c.w. power amplifier requiring no neutralization, as a Class-B linear, suppressor-modulated amplifier, control-grid modulated amplifier, and plate-modulated amplifier. Following are the tentative ratings on the tube:

Filament voltage	10 volts
Filament current	5 amps.
D.C. plate voltage	2000 volts max.
D.C. screen voltage	400 volts max.
D.C. suppressor voltage	45 volts max.
Plate dissipation	100 watts
Screen dissipation	35 watts
D.C. grid current	25 ma. max.
R.F. grid current	5 amps. max.
Interelectrode capacitances:	
Grid-plate	0.012 $\mu\mu$fd.
Input	11.0 $\mu\mu$fd.
Output	10.0 $\mu\mu$fd.

WHAT THE NEW TUBE CAN DO

The power amplification ratio obtainable with the RK-28 is tremendous compared with that realized in triodes of similar output rating. The grid driving power required for full output is quite small—a few watts at most. A typical set of operating conditions specified by the manufacturer is given in the following table:

Plate voltage	2000 volts
Screen voltage	400 volts
Suppressor voltage	45 volts
Control-grid voltage	−100 volts
Plate current	140 ma.
Screen current	60 ma.
Screen dropping resistor	26,000 ohms
Control-grid current	10 ma.
R.F. driving voltage	180 volts
R.F. driving power	1.8 watts
Power output	200 watts

It should be pointed out that the measurements in the above table were made in a test set-up operating at 800 kilocycles, and it is therefore natural to expect that because of higher losses the figures would not be quite so favorable at amateur frequencies. However, the tube was given as thorough a test as the limited time permitted in the experimental rig shown in the photograph, and although no attempt was made to make actual measurement of the driving power required it was obviously very low. At 3.5 mc. the tube could easily be driven to full output by a 47 oscillator, more than 200 watts being put into a dummy load with the plate showing no color. D.C. grid current of 5 to 10 ma. represented optimum excitation (bias 90 volts); higher grid current caused a reduction in output and efficiency. Positive suppressor bias is a necessity if best operation is to be obtained; there is a very marked improvement in both output and efficiency with the suppressor about 45 volts positive. Increasing the screen voltage beyond the recommended 400 volts resulted in no apparent increase in output, although causing the plate current to rise. The control-grid bias is not critical; the 100-volt figure recommended above is broadly optimum for efficient operation. If a grid leak is used it should have a value of about 10,000 ohms. At 14 mc. the tube operated equally well, showing about the same output as at 3.5 mc. with the same d.c. grid current. Increasing the grid current beyond the region of 5 to 10

milliamperes again caused a reduction in output and efficiency.

The tube also operates well as a doubler, giving about 100 watts output without exceeding the plate rating. The excitation requirements are similar to those for straight amplification.

SUPPRESSOR MODULATION

Since the carrier plate efficiency with suppressor modulation is a fairly fixed quantity running between 30 and 35 percent, the fundamental factor limiting the output is the tube's rated plate dissipation, assuming the filament emission is ample. This is the case with the RK-28; at the present conservative 100-watt rating the carrier output obtainable is in the neighborhood of 60 to 65 watts. The operating conditions listed below actually represent two modulation methods; the left-hand column gives the figures for suppressor modulation alone, using fixed screen voltage; those at the right are for combined suppressor and screen modulation.

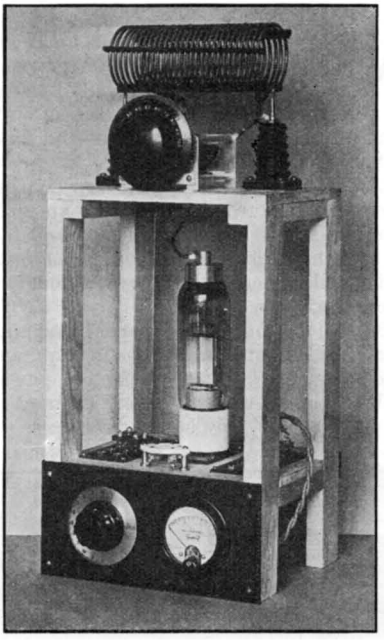
	Supp.	*Supp. and Screen*
Plate voltage	2000	2000 volts
Screen voltage	400	400 volts
Grid voltage	−100	−100 volts
Suppressor voltage	−50	−50 volts
Plate current	80	85 ma.
Screen current	85	85 ma.
Grid current	11	11 ma.
Peak audio supp. voltage	90	90 volts
Peak audio screen voltage	—	200 volts
A.F. power for full modulation	0.4	7.6 watts
R.F. driving power	2	2 watts
Carrier output	60	65 watts

The higher audio power required in the case of combined suppressor-screen modulation results from the demand on the audio system imposed by the rather low effective screen resistance. The audio swing on the screen is approximately twice that on the suppressor, the actual value not being critical. The combined suppressor-screen system extends and straightens the modulation characteristic, giving somewhat higher output with less distortion. In particular, it brings the characteristic down more sharply to zero, lessening the familiar "tailing off" at the lower end.

A trial of suppressor modulation in our experimental set showed that excellent quality is obtainable. Neither of the sets of conditions shown above were exactly duplicated in this test, the screen being fed through a dropping resistor of about 25,000 ohms from the plate supply and allowed to swing at an audio rate determined by the tube characteristics[1]. This gives about the same effect as combined suppressor and screen modulation, although avoiding the necessity for a second audio source. The suppressor bias is not critical so long as it is in the region of 45 to 67 volts, although the selection of suppressor bias within this range to some extent determines the carrier output.

[1] "Screen-Grid Supply with Suppressor Modulation", *QST*, March, 1935.

In connection with suppressor modulation, it should be mentioned that the excitation and loading adjustments must be made with some care. As in the case of any grid-modulated amplifier, the adjustments should not be carried out with the idea of obtaining maximum carrier output for the allowable input[2]; this usually gives too high plate efficiency with the result that the modulation characteristic flattens off on the upeaks. In practice this means that the antenna



THE NEW RK-28 PENTODE IN AN EXPERIMENTAL TEST SET-UP

A quarter kilowatt output with only a few watts driving power is only one of the things we like about this tube. With suppressor modulation a carrier output of 65 watts or more is readily obtainable, the audio power required being less than one-half watt.

current does not kick up on modulation—it may kick downward—and modulation is accompanied by a drop in d.c. plate current. Using the RK-28 we found it necessary to over-excite the tube—grid current about 10 to 15 ma. against the 5 ma. or so which gave maximum output—to get a linear modulation characteristic. In general, the conditions for suppressor modulation with any r.f. pentode will differ from those for c.w. amplification by requiring somewhat more excitation, relatively high screen current, and a decrease in plate efficiency.

OTHER TYPES OF MODULATION

The RK-28 can be used as a control-grid modulated amplifier, giving a carrier output of

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[2] "Grid-Bias Modulation for the General Purpose Transmitter," *QST*, March, 1935.

not oscillate reliably. The only requirement of this circuit is a separate filament winding for the regulator tube when using center-tap keying.

The circuit shown in Fig. 2, using indirectly-heated tubes (2A5's) obviates this necessity. At first thought it might appear that the full plate voltage would be applied between cathodes and heaters when the key is open. This is not the case, since the only voltage appearing here is the cut-off voltage, or approximately 30 volts with a screen voltage of 150. Also, due to the large dropping resistor in the screen lead, the screen voltage is reduced very much below normal when the key is first closed and all three tubes are taking current, thus more thoroughly suppressing key clicks and thumps. In fact, key clicks did not appear in an ordinary broadcast receiver sitting on the same shelf with the transmitter.

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about 75 watts. Plate and screen voltage are the recommended maximum values, the screen being supplied from the plate power source through an 80,000-ohm dropping resistor. The screen current under these conditions is about 20 milliamperes. The suppressor should be operated 45 volts positive. The control grid should be biased 140 volts negative and supplied with a peak r.f. voltage of 160 volts. Grid current under no-modulation conditions is less than 2 milliamperes. The peak audio grid swing required is 60 volts. Plate current should be adjusted through loading to 88 milliamperes. Excitation requirements are the same as for suppressor modulation.

As a Class-B linear amplifier the grid bias should be –38 volts, assuming plate and screen voltages of 2000 and 400, respectively. The suppressor should be connected back to filament center-tap. The screen will take 30 milliamperes through a 55,000 ohm dropping resistor. With plate load adjusted to make the tube draw 75 milliamperes, the carrier output is approximately 50 watts. The driving power, exclusive of power dissipated in a regulating resistor, is about one watt.

The tube also can be plate modulated provided the screen is simultaneously modulated as with screen-grid tubes. Present ratings for this type of service specify the maximum plate voltage as 1500, the carrier output being approximately 100 watts. The pure-tone audio power needed for complete modulation is 82 watts for the plate (1500 volts d.c. at 110 ma.) plus 18 watts for the screen; or, if the screen is supplied through a dropping resistor which also consumes audio power, a total of 150 watts. We have operated the tube as a plate-screen modulated amplifier with 2000 on the plate, exceeding the present rating by 500 volts, with no sign of breakdown. The excitation requirements are quite low, running in the vicinity of a few watts. The question of plate modulation of pentodes will be discussed more completely in an early issue.

CIRCUITS

The RK-28 can be used in any of the circuits which are employed with other r.f. pentodes. Partly for this reason and partly because sample tubes were received at such a late hour that time did not permit running through preliminary tests on the tubes and getting drawings made in time for this issue, none are shown here. The experimental rig shown in the photograph was built up so that all kinds of circuits could be tried without necessitating rewiring, and hence is equipped with a large number of plugs and jacks for circuit changing which would not be required in an ordinary layout.

No shielding about the tube was found necessary, since it has shown no tendency toward self-oscillation when driven from a separate source. By supplying a small amount of feedback—such as bringing a wire from the plate near a similar wire from the grid—the tube will function excellently as a pentode crystal oscillator. Using 2000 volts on the plate and with the feedback "condenser" adjusted so that the r.f. crystal current was less than 100 mils under no-load conditions, an output of 200 watts or better was readily obtainable. The crystal was under no more strain than when used in the ordinary 47 circuit with 400 or so on the plate. Operation of this type illustrates the ease with which the tube can be excited.

As a Tri-Tet oscillator the tube behaves about like the RK-20. Time did not permit a very complete investigation of its suitability for this type of work. The plate voltage was not raised beyond 1000 at which voltage the output was about the same as that obtainable from the RK-20.

With the new tube it should be no trouble at all to build a multi-band 250-watt c.w. transmitter using only receiving tubes at low voltages in the exciter. In such a rig band-switching does not appear so nebulous—in fact, it should be readily attainable. We have something of the sort in mind for an early *QST* issue.

—*G.G.*

Hamdom

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the 160-meter Army Net, member of the original OT5 chapter, member of the I.R.E., A.R.R.L. 'Phone Activities Manager, director in the New England Division Radiophone Association, chairman of the planning board of the South Shore Radio Club, lieutenant in the Massachusetts National Guard, and—but that's all we have space to tell. Except that you can call him "Mark," instead of "Mac," and he'll still know you're calling.