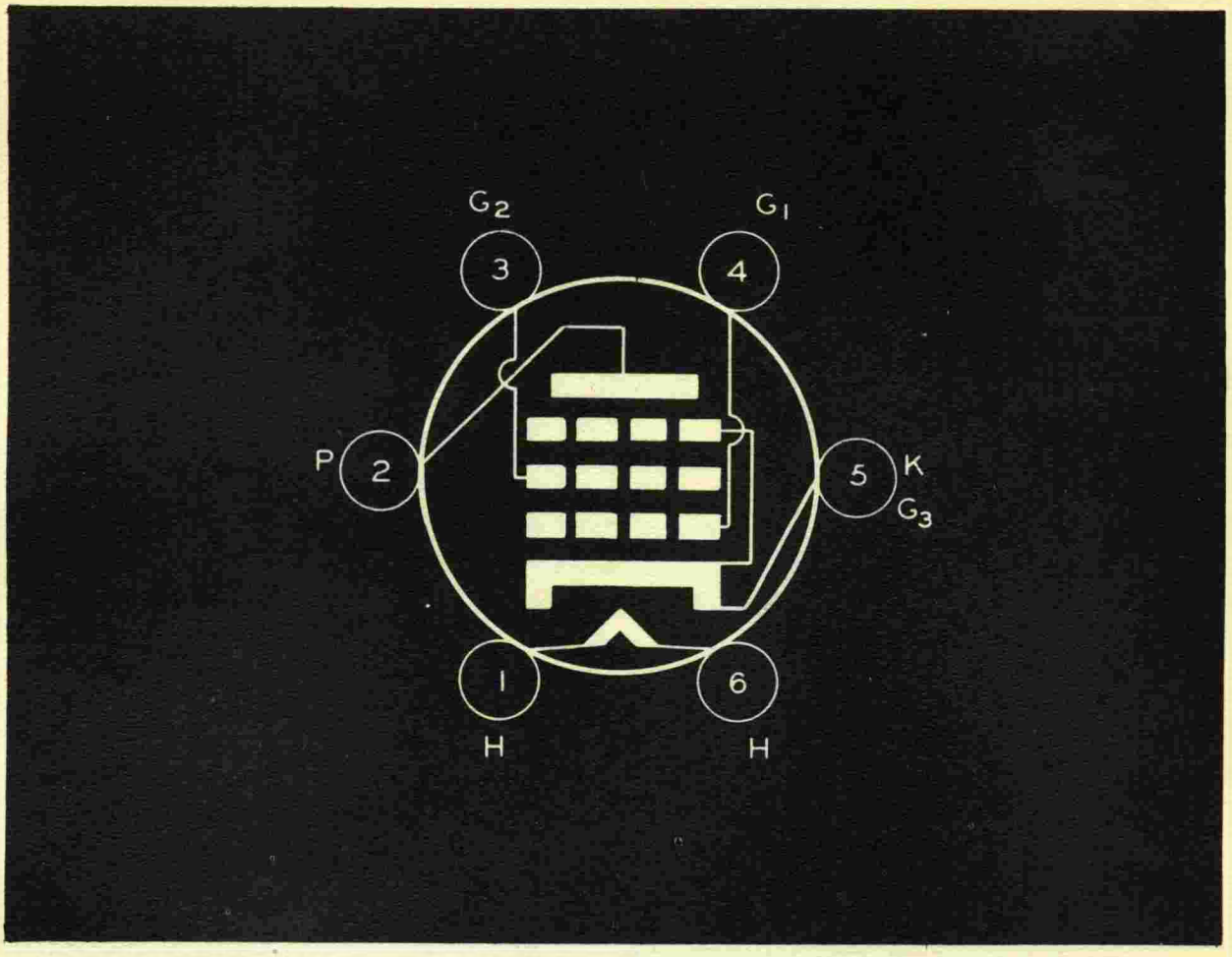

LESSON
18 R

POWER OUTPUT PENTODES

RADIO-TELEVISION TRAINING SCHOOL, INC.
ESTABLISHED 1922
LOS ANGELES

RADIO-TELEVISION TRAINING SCHOOL, INC.
5100 SOUTH VERMONT AVENUE • LOS ANGELES 37, CALIFORNIA, U. S. A.

POWER OUTPUT PENTODES

The pentode was developed to make available an output tube with a higher amplification factor and a better operating efficiency. After much experimental work these results were finally obtained by eliminating some conditions that limited the performance of the former output tubes. One of these was the negative space charge that accumulated around the filament of the tube, and the other was the so-called secondary emission from the plate. Both of these were overcome in a really simple manner.

In the early discussion of the screen grid tube it was clearly shown how a cloud of electrons accumulates around the filament, and how these electrons in a group form a strong negative charge throughout the surrounding space. This collection of electrons is called the space charge, and its effect is to hinder and oppose the release of more electrons from the filament. In this manner, it greatly limits the permissible plate current. Since the effectiveness of a tube as an amplifier depends upon the extent to which the grid potential variations affect the flow of plate current, that is the movement of electrons between the filament and the plate, the space charge also reduces the amplifying qualities of the tube. With the heavy space charge present a small change in grid potential will not affect the plate current as appreciably as it would if the space charge were not present.

In the pentode, as in the screen grid tube, this space charge is counteracted or neutralized by the presence of another element or grid that carries a positive charge. This element is known as the screen grid or space charge grid, and is inserted on the plate side of the control grid. The positive charge on the screen grid attracts the negative space charge electrons; but since this grid is a coarse mesh, only a few electrons actually strike it, and therefore only a small screen grid current flows. This current, of course, is wasted energy but fortunately is negligible in amount. The rest of the electrons are so speeded up by the positive force on the space charge

grid that instead of landing on this element they pass right on through to the more distant, but also positively charged plate.

With the space charge thus removed, or at least greatly reduced, the plate voltage becomes more effective, for the electrons in their passage from the filament (or cathode) to the plate need not overcome the retarding influence of the space charge. Also, slight variations in grid potential are more capable of affecting the plate current flow than if the space charge were present. Expressed in other words, eliminating the space charge enables the tube to operate at a higher amplification factor. This is one of the features sought for in an improved output power tube, the other being a greater power output as compared to the input requirements.

CONSTRUCTION OF THE TYPE 47 A. C. PENTODE

As was previously explained, the pentode is essentially a screen grid tube with an extra element or grid that so changes the operating characteristics of the tube that it can be used as an output audio amplifier. In this manner a higher degree of sensitivity is imparted to the audio output circuit, so that it is possible to obtain a large volume of undistorted output even with signals that are comparatively weak when they reach the audio system.

A commonly used A. C. power pentode is the No. 47 tube. As the name suggests, the pentode has five elements or electrodes. It employs a coated electron emitting filament designed primarily for A. C. operation at a normal rated voltage of 2.5 volts. The filament current consumption is 1.5 amperes. Immediately surrounding the filament is the control grid, which corresponds to the grid found in ordinary power tubes. It receives the signal impulses and influences the movement of electrons accordingly. The function of the screen grid is to overcome the space charge that tends to clog the action of the tube. The next element in the tube is the suppressor grid (or cathode grid), used for the purpose of neutralizing or suppressing the secondary

electron emission from the plate. The space charge grid or screen is generally operated at a positive potential of 250 volts, but the suppressor grid is internally connected to the center of the filament and therefore is at practically zero or ground potential. The fifth element is the plate, which as in all tubes is operated at a high positive potential, and in the case of the type 47 pentode at a rated pressure of 250 volts.

This construction of the A. C. power pentode is illustrated diagrammatically in Fig. 1.

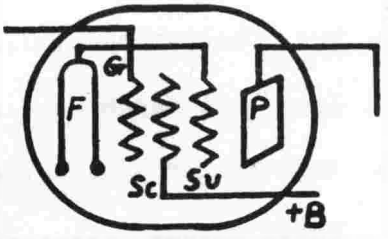

Fig. 1.

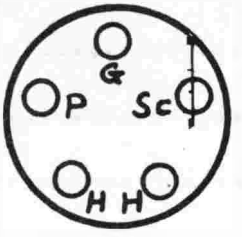

Fig. 2

Fig. 1.—Arrangement of the elements in a type 47 output Pentode.
Fig. 2.—Base pin arrangement of the 47 Pentode, looking at bottom of tube.

As is illustrated, the filament "F" is supplied with current from the 2 1/2-volt secondary of a suitable power transformer. Next to the filament is the control grid "G" which receives the input signal voltages. Surrounding this is the space charge grid "Sc." which receives a positive potential of 250 volts and draws a current of about 7 milliamperes. Then comes the suppressor grid "Su," which is connected to the center of the filament "F" and is at zero potential. Beyond this is the plate "P" which as in all tubes is operated at a high positive potential.

The A. C. pentode type 47 is identical in size and dimensions with the type 45 output tube, except that it employs a standard five-prong base as illustrated in Fig. 2. The identification of the five prongs is similar to that of the 27 tube, except that the cathode prong is the space charge or screen grid prong in the case of the 47 tube. Since the suppressor or cathode grid is electrically connected to the center of the filament inside of the tube, no external connection need be provided for this element. The tube thus fits into the standard five-prong "UY" socket.

ELECTRICAL CHARACTERISTICS OF THE NUMBER 47 PENTODE

In the following table are given the electrical operating characteristics of the 47 pentode tube. It is recommended by the tube manufacturers that these values be adhered to as closely as possible in order to obtain best results from the tube.

OPERATING CHARACTERISTICS

Filament Voltage	2.5 Volts	Screen Current	6 Mills
Filament Current	1.5 Amps.	Plate Impedance	60,000 Ohms
Plate Voltage.....	250 Volts	Mut. Conductance	2,500 M'mhos
Screen Grid Volts.....	250 Volts	Load Resistance	7,000 Ohms
Cont. Grid Volts .....-16.5 Volts		Amp. Factor.....	150
Plate Current.....	32 Mills	Power Output	2,500 M'Watts

REPLACING OUTPUT TUBES WITH PENTODES

The advantage of the pentode power tube, it was pointed out, is its greater power output capacity at a relatively lower grid swing. In other words, it is a power output tube with a higher amplification factor, and is more economical in cost of operation. When employed in circuits designed for its use, the pentode gives quite satisfactory results; but if it is attempted to substitute it in circuits employing other power tubes, such as the 45 tube for example, a different situation presents itself.

In any well designed circuit, either of the tuned radio frequency or the super-heterodyne type, the amplification gain is calculated so that the signal voltage at the time it reaches the output tube is high enough to produce full grid swing, which in the case of the 45 tube is about 50 volts. It is at once evident that if a pentode were substituted directly for a 45 tube, it would be overloaded by over 200 per cent, for the maximum grid swing for distortionless output with the pentode is only 16 volts. A reduction in signal strength is necessary. This could be done by reducing the sensitivity

of the R.F. amplifier, but this would decrease the pick-up ability of the receiver for weak signals, and if carried too far would introduce serious distortion. The method is accordingly not to be recommended. Another scheme would be to eliminate the first audio stage and employ resistance coupling between the detector and the pentode. This might work out fairly satisfactorily, but if the cost of making this change is considered as well as the other necessary alterations, no saving would be gained. Another point that needs consideration if such a replacement is contemplated, is the plate impedance of each tube and the recommended load resistance. Since these values differ widely in the 45 and 47 tubes, a change in output transformers would also be necessary if the tubes were changed. The bias resistor would likewise have to be changed, for while the 45 tube requires a grid bias of 50 volts at a plate pressure of 250 volts, the 47 pentode needs only 16.5 volts under the same conditions.

After all is considered, that is the circuit conditions that would require change or adjustment and the parts that would need replacement, very little, if anything, would really be gained by replacing a 45 tube with a 47 pentode, especially if there is ample R. F. amplification and a sufficiency of power output from the power tube, in use. It is not a change that the service man can conscientiously recommend to his customers as a means of improving their sets and bringing them more up to date. An exception might be the case of an older or poorly designed receiver that hasn't the output desired, for under these conditions the substitution of a pentode in the last stage would materially aid the output.

THE TYPE 33 POWER OUTPUT PENTODE

The type 33 tube is a two-volt power amplifier pentode developed to improve the performance of battery operated receivers employing the 2-volt air cell battery or other battery power where economy of filament current drain is important. The 33 pentode offers the same advantages in its field as the type 47 does in A. C. receivers.

The type 33 pentode is similar in construction to the type 47 in that it has the same five elements, but on account of the lesser power requirements is somewhat smaller in size. The filament is of the coated type rated at 2 volts, and consumes a current of 0.26 ampere. Next to the filament is the control grid, and surrounding the control grid is the screen grid. The outermost element is the plate. The suppressor grid is located between the plate and the screen, and is electrically connected to one side of the filament, that is to the filament prong adjacent to the screen grid terminal.

The 33 pentode employs a five-prong base that fits into a standard "UY" socket. The base connections are as follows: The filament terminals to the standard heater prongs, the control grid to the grid prong as with the 27 tube, the screen grid to the cathode prong and the plate to the normal plate prong. The suppressor grid is internally joined to the heater prong adjacent to the screen grid prong. In the following table are given the operating characteristics of the 33 pentode.

OPERATING CHARACTERISTICS

Filament Volts.....	2.0	Screen Current.....	3 Mills
Filament Amperes	0.26	Mutual Conductance.....	1,450 Micromhos
Plate Volts.....	135.	Amplification Factor	70
Grid Volts.....	-13.5	Plate Resistance	50,000 Ohms
Plate Mills.....	14.5	Load Resistance.....	7,000 Ohms
Screen Volts.....	135.	Power Output.....	700 Milliwatts

On account of its high amplification factor, the 33 pentode makes it possible to omit a first audio stage and still deliver a large output to the speaker. This effects a saving of the filament and plate current drain of one tube, which in battery operated receivers is an appreciable economy. As indicated in the table above, the maximum undistorted power output is 700 milliwatts, and this is nearly equal to the output of a type 71A tube operated at a plate pressure of 180 volts, while the 33 tube requires

only 135 volts. The plate impedance of the tube is very high, 50,000 ohms, and for best results, therefore, the load resistance should be maintained at the recommended value of 7,000 ohms.

THE TYPE 38 POWER OUTPUT PENTODE

The type 38 tube is also a power output pentode; and although it was intended primarily for automobile radio service, it is also used in other types of radio receivers. This tube employs an indirectly heated cathode, the heater element being designed for a 6.3-volt power supply. The current consumption is only 0.3 ampere, and either direct or alternating current can be used. The power output at 135 volts plate pressure is 525 milliwatts, a little less than that of the 71A tube at 180 volts. The suppressor grid, which limits the secondary emission at the plate, is connected internally to the cathode and is therefore at the same potential.

The 38 tube employs the small five-pin base that fits into the standard "Y" socket. Looking at the base of the tube with the heater pins toward the observer, the arrangement of the pins starting with the left hand heater pin and going around in a clockwise direction is: Heater, plate, screen, cathode, heater. The control grid is brought out to a metal cap at the top of the tube. To maintain the output as high as possible and the distortion at a minimum, the load impedance should be maintained fairly constant at the recommended value. If the tube is self-biased, the biasing resistor should be bypassed by a large condenser.

OPERATING CHARACTERISTICS

Filament Volts.....	6.3	6.3	Plate Resistance....	84,000	102,000
Plate Volts.....	100.	135.	Mutual Conductance.....	950	975
Grid Volts.....	-9.	-13.5	Plate Mills.....	7	9
Screen Volts.....	100.	135.	Output Milliwatts.....	200	525
Amplification Factor....	80.	100.	Load Impedance.....	8,500	13,500

THE TYPE 41 POWER OUTPUT PENTODE

The type 41 tube is a power amplifier pentode, also of the indirectly heated cathode type, designed for operation from a 6.3-volt power supply, A. C. or D. C., with a filament current consumption of .4 ampere. It also was intended for automobile radio service, but can be used effectively in other types of receivers just as well, provided the plate supply does not exceed 180 volts. At this plate pressure and a -14-volt grid bias the tube will deliver an output of 1,500 milliwatts. For greater output two tubes can be used in push-pull. If a single 41 tube is self-biased, the resistor must be shunted by a large bypass condenser to prevent any degenerative coupling effects.

OPERATING CHARACTERISTICS

Plate Volts	125	167.5	180 Max.
Screen volts.....	125	167.5	180 Max.
Grid Volts.....	-10	-12.5	-13.5
Amplification Factor.....	150	150	150
Plate Resistance.....	100,000	85,000	81,000
Mutual Conductance.....	1,525	1,800	1,850
Plate Current.....	11	17	18.5
Screen Current.....	2	3	3
Load Resistance.....	11,000	9,500	9,000
Output (Milliwatts)	650	125	1,500

THE TYPE 42 POWER OUTPUT PENTODE

The type 42 tube is also an indirectly heated cathode type power output pentode, larger in size than the type 41 and designed for operation on plate voltages up to 250 volts. It can be operated from a 6.3-volt A. C. or D. C. power supply, and has a

maximum power output of 3 watts, which is greater than that of the 47 pentode. It has the additional advantages that the separate cathode makes the tube practically hum free, makes complete self-bias operation possible, and eliminates the need of a center tap on the filament winding. The tube is of rugged mechanical construction and is an extremely efficient power output tube. It is used in push-pull in the output stage of a number of high-grade A.C. operated receivers that employ 6.3-volt tubes in the remainder of the circuit system.

OPERATING CHARACTERISTICS

Filament Volts	6.3	Plate Resistance	75,000
Filament Amperes	.65	Mutual Conductance	2,200
Plate Volts	250.	Amplification Factor	165
Grid Volts	16.5	Load Resistance	9,000
Plate Mills	34.	Output (Watts)	3
Screen Volts	250.		

The 42 pentode has a six-pin base, and has the suppressor grid connected internally to the cathode. Looking at the bottom of the base of the tube and proceeding in a clockwise direction from the left heater pin, the pin connections are: Heater, plate, screen grid, control grid, cathode and heater.

THE TYPE 43 POWER OUTPUT PENTODE

The No. 43 tube is a 25-volt power output pentode of the indirectly heated cathode type designed especially for use in the output stage of D. C. line operated receivers. However, it is also used extensively in the universal A.C.-D.C. midget sets as an output tube. At a plate pressure of 95 volts, it can supply 900 milliwatts output. Resistance coupled input is generally used with the tube. The heater current is .3 ampere, and therefore the tube can be operated in a series system with other 6.3-volt

tubes having the same filament current. The No. 43 pentode also has the suppressor grid tied internally to the cathode and is equipped with a six-prong base. The pin arrangement in a clockwise direction beginning at the left hand heater pin when one looks at the bottom of the base is: Heater, plate, screen grid, control grid, cathode and heater.

OPERATING CHARACTERISTICS

Filament Volts.....25.	Plate Mills.....20
Filament Amperes.....3	Plate Resistance.....45,000
Plate Volts.....95.	Mutual Conductance.....2,000
Screen Volts.....95.	Amplification Factor.....90
Grid Volts.....-15.	Load Resistance.....4,500

Output 900 Milliwatts

THE TYPE 48 POWER OUTPUT TETRODE

The No. 48 tube is a 30-volt, 0.4-ampere, heater type power tetrode designed for use in the output stage of D.C. line operated receivers. The maximum plate operating voltage is 125 volts. The proper grid bias is 22.5 volts, and the plate current drain is 50 milliamperes. Under these operating conditions the available power output is 2.5 watts. The tube employs a six-pin base, with the same pin arrangement as with the type 43 tube described in the previous section.

OPERATING CHARACTERISTICS

Filament Volts.....30.	Screen Volts.....95
Filament Amperes.....4	Plate Resistance.....10,000
Plate Volts.....95.	Mutual Conductance.....2,800
Grid Volts.....-20.	Amplification Factor.....28
Plate Mills.....47.	Load Resistance.....2,000

Output 1,600 Milliwatts

THE TYPE 18 POWER OUTPUT PENTODE

The No. 18 tube is also a cathode type power output pentode with a heater rating of .3 ampere at 14 volts. Its operating characteristics are otherwise similar to those of the type 42 pentode described above. The type 18 tube can be used in an 0.3-ampere series filament system, and is specially applicable in universal A.C.-D.C. receivers. For operating values, see the table given on Page 9 for the type 42 pentode. Both tubes also have six-pin bases with the same pin arrangements.

THE 2A5 POWER OUTPUT PENTODE

The 2A5 tube is a power amplifier pentode of the heater-cathode type for use in the output stage of A. C. operated receivers. It is capable of giving a large power output (3 watts) with a relatively small input-signal voltage. In a push-pull system the available output would be 6 watts. The tube has a six-prong base that fits into the standard six-pin socket. The pin arrangement in a clockwise direction beginning at the left hand heater pin when one looks at the bottom of the base is: Heater, plate, screen grid, control grid, cathode and heater.

If a single 2A5 is used and is self-biased, a 400-ohm resistor must be used, if the applied plate pressure is 250 volts. This resistor must be shunted by a large by-pass condenser in order to prevent any degenerative coupling effects. If two 2A5 tubes are used in push-pull, a 200-ohm bias resistor is needed, but as was explained previously, the large by-pass condenser is not required here. Either resistance or transformer input coupling can be employed with the 2A5 pentode, and of course, an output transformer with the proper primary impedance must be used, and this plate impedance should be held as uniform as possible over the entire audio-frequency range.

OPERATING CHARACTERISTICS

Filament Volts.....	2.5	Screen Mills.....	6.5
Filament Amperes.....	1.75	Plate Resistance.....	7800.
Plate Volts.....	250.	Amplification Factor.....	220.
Screen Volts.....	250.	Mutual Conductance.....	2500.
Grid Volts.....	-16.5	Load Resistance.....	7000.
Plate Mills.....	34.	Output (Watts).....	3.1

EXAMINATION QUESTIONS ON FOLLOWING PAGE