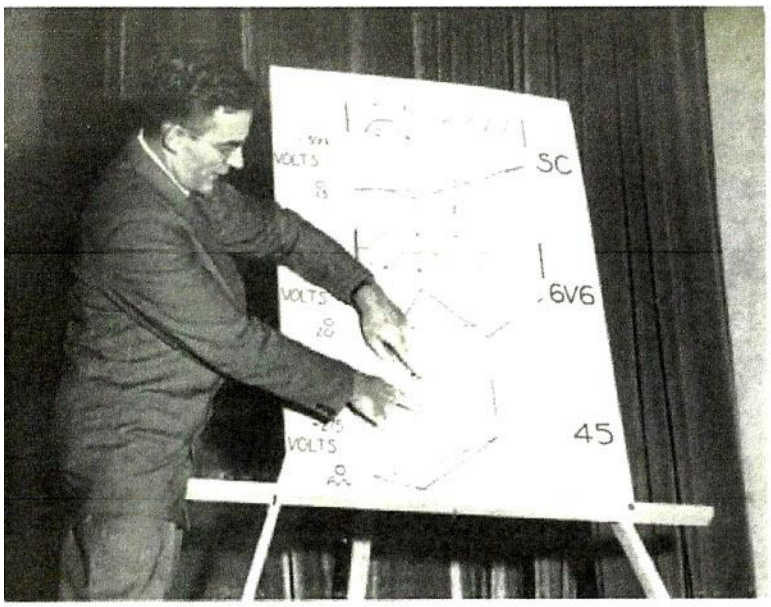


Advantages of

Describing new application of an old principle—the space-charge-grid output tube achieves triode performance at tetrode efficiency.

Norman C. Pickering pointing out the lines of equal potentials within the structure of a triode, as compared to those in the beam and space-charge tubes. The solid lines on the chart represent conditions between the cathode at the left side of each diagram, and the plate at the right when the control grid is at zero-signal conditions. The dotted lines represent conditions at maximum positive swings of the control grid.

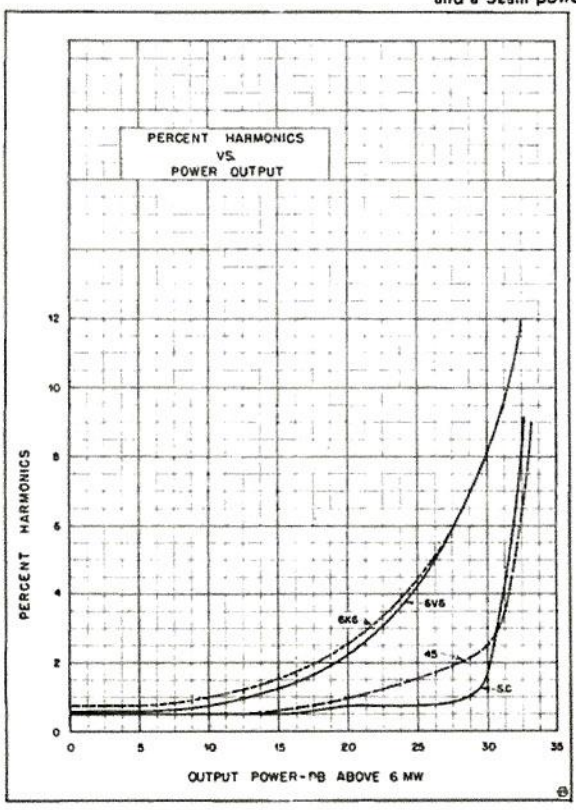
NORMAN C. PICKERING, designer of the magnetic pickups and cartridges bearing his name, presented a paper on the space-charge-grid output tube at a meeting of the New York section of the Institute of Radio Engineers held in the Western Union auditorium on Sept. 18.

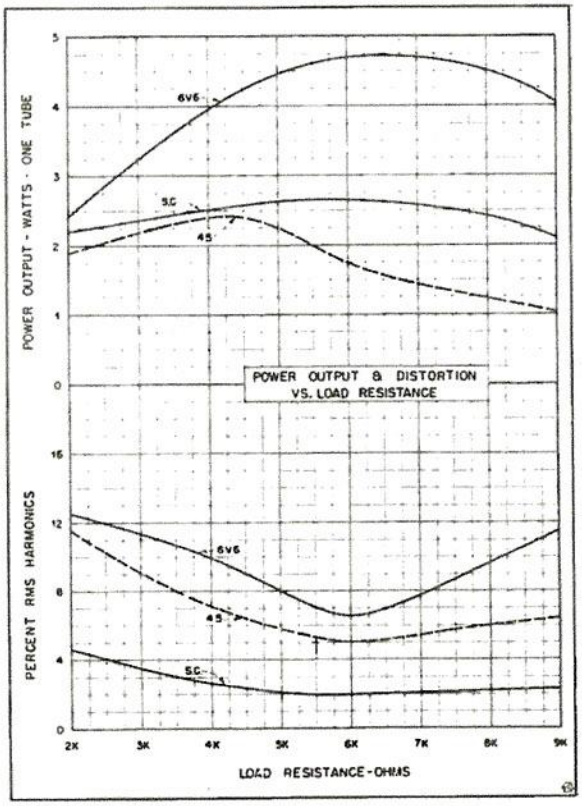
While the investigation of this tube was started in the early 30's, the advent of the beam power tube effectively overshadowed the space-charge tube, and it was never introduced publicly. The desire for the lowest possible distortion caused the tubes to be resurrected, and further measurements have shown them to have many advantages. Triodes, of course, have long been favored for low-distortion amplifiers, but they are hard to drive properly. Pentodes and beam-power tubes are easier to drive, but have intrinsically higher distortion. The tests on the space-charge-grid tube show it to combine the low distortion characteristics of the triode with the easy-to-drive characteristics of the beam power tube.

This tube has certain points of similarity to the beam power tube in construction, using two grids aligned in the same manner. The spacing between cathode and the space-charge grid is greater than is customary with beam power types. The low positive potential applied to the space-charge grid causes the effective cathode diameter to be increased appreciably, and the tube is able to perform in a manner similar to a triode without the necessity for the control grid to be in close proximity to a thermally heated cathode, with its attendant disadvantages.

If an ordinary beam power tube were connected as a space-charge tube, the cur-

Per cent harmonics vs. power output, and (right) power output and distortion vs. load resistance for a typical triode, a space-charge-grid tube, and a beam power tetrode.





Space–Charge–Grid Output Tubes

rent drawn by the space-charge grid would be excessive, due to the close positioning with respect to the cathode. In the experimental tubes, this was overcome by mounting a pair of side rods between the space-charge grid and the cathode, and connecting these rods to the control grid, thus shielding the space-charge grid from the cathode in the areas where the effect of the first grid is not necessary. The voltage for the space-charge grid is obtained from the plate supply through an unbypassed series dropping resistor, the absence of a bypass capacitor causing some degenerative action on the signal current. The tube is not critical with respect to load resistance.

A comparison between the space-charge tube and the types now in use—triodes and beam power tubes—involved the construction of three separate amplifiers, using nearly identical circuit arrangements, the same output transformer, and the same power supply. Since the only available space-charge tubes were relatively small, the comparison was made between them, the 45 representing the triodes, and the 6V6 representing the beam power tubes.

Measurements of power output, and intermodulation and harmonic distortion were made on the three amplifiers, each being arranged for optimum load impedance, and the results indicated some promise. In practically every test, the space-charge tube was superior to the others.

The space-charge tubes were about twice as good as the triodes at low values of harmonic distortion, with the latter being about 1 db better on the intermodulation tests. The effective amplification of low-mu triodes is naturally small, and while the mu of the 6V6 is 230, the useful gain, considering the high plate resistance of the tubes and the low value of load required for optimum operation, is only about 13.3. The space-charge tube with a mu of 20 manages to afford a useful gain of 16.6.

Damping Factor

The damping factor, a result of the effective generator impedance, varies considerably with the tube types. The impedance of the generator, as seen from the load, is five times the load resistance in the case of the beam power tube, 0.8 times the load resistance for the triode, and 0.5 times for the space-charge tube. This property makes for cleaner bass response and the elimination of "hangover," an effect so objectionable with pentodes and beam power tubes. One additional advantage of the low effective generator impedance is the prevention of a voltage rise at high frequencies; with the space-charge tubes, there is less necessity for the use of inverse feedback.

While the plate-to-plate load for the space-charge tubes was found to be higher than for either the triodes or the beam tubes, no more primary inductance is required in the transformer, it being necessary only to match the impedance of the loudspeaker properly by reducing the secondary turns in the output trans-

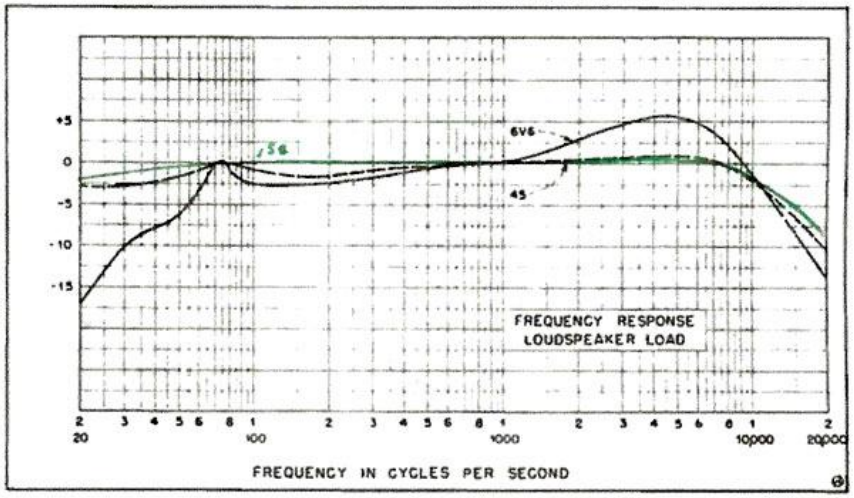
[Continued on page 45]

TABLE I

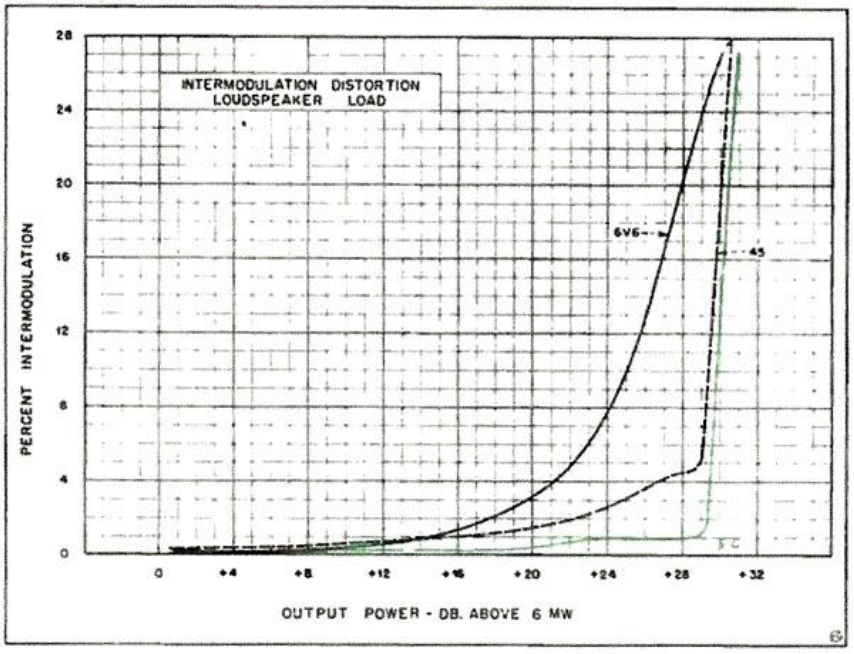
(Values are for two tubes)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Tube type	Plate res ohms R_P	Transconductance G_M	Ampl factor μ	Plate supply volts E_B	Total cathode current ma	Total dc input watts	Optimum load res-ohms R_L	Ultimate power output watts	Peak grid volts for ult pwr out	Power at 5% harm watts	Power at 2% harm watts	Power at 10% intermod watts	Eff at 5% dist	Gain $\frac{\mu R_L}{R_L+R_P}$	Gen speed at 500 Ω top ohms
6V6	65,000	3,600	230	285	74	21.2	8,000	12.5	42	2.4	.32	.76	11.3%	13.3	2,500
6K6	75,000	2,100	150	285	62	17.7	12,000	8.5	54	2.4	.50	.61	13.5%	11.1	2,000
SC	4,000	5,000	20	325	110	35.7	20,000	11.0	36	10.7	6.6	4.8	30.0%	16.6	250
45	1,700	2,050	3.5	325	92	29.8	5,000	13.5	150	12.0	3.8	6.0	40.0%	2.6	400

Characteristics of typical tetrodes, space-charge-grid tube, and a triode.



Comparative frequency-response vs. speaker load for three tube types. Below, intermodulation distortion vs. loudspeaker load curves.



Space--Charge--Grid Tubes

[*from page 21*]

former. This reduces the transformer cost, and also reduces losses in the secondary winding, and leakage inductance. A primary inductance of 10 henries is sufficient for response to within 1 db down to 30 cps.

The input-output curves for the three types of tubes were also compared, and the space-charge tube was better in this respect. The 6V6 curves depart from linearity about 10 db below the maximum output point, while the space-charge tubes were linear up to 3 db below the maximum output. The triodes were intermediate to these two values.

The aural demonstrations accompanying Mr. Pickering's talk were conclusive proof of the advantages of the space-charge tubes. Using a modified Klipsch speaker system, the low-frequency response was notably freer from hangover and from distortion in the higher frequencies. However, when reproduced through a good quality 12-in. speaker mounted in a conventional bass reflex cabinet of about 3 cu. ft. volume, the hangover effects of the 6V6 amplifier were particularly objectionable, and the performance of the space-charge tubes was seen to be definitely superior to that of the beam power tubes. In all particulars, the performance of the space-charge tubes was equal to or better than that of the triodes.

Unfortunately, these tubes are not yet in production. The response to the paper and the obvious advantages of the new tubes will govern the future steps of the designers. Your reporter has already placed an order for a pair of them as soon as they become available. It is contemplated that these tubes will be made in two power capacities, one being in the range of the 6V6 while the other will correspond roughly to the capacity of the 6L6.