14·4. Tetrodes and Pentodes.—Tetrodes and pentodes are most conveniently classified according to function rather than to structure, and the tubes of this section will be classified primarily as r-f amplifiers or as power output tubes. There are many tubes which might be considered as belonging in either or both of these categories, but the great majority fall clearly into one or the other class.

R-f Amplifiers.—R-f and i-f amplification in radio receivers is now almost invariably obtained from small pentodes, which may be classified on the basis of their cutoff characteristics into sharp-cutoff and remote-cutoff types. The latter type is occasionally and rather meaninglessly designated the "super control" type, and in some tube lists the former type is vaguely called a "triple grid amplifier." Some tubes are intermediate in character between the two classes, and are called "semiremote-cutoff" pentodes; they may most conveniently be classed with the remote-cutoff tubes.

Sharp-cutoff pentodes have Eg-Ip characteristics such that plate current and transconductance decrease to practically zero when the control grid is made a few volts negative. In a remote-cutoff pentode they will decrease rapidly at first with increasing negative grid bias, but the rate of decrease becomes less and the quantities become essentially zero only when the negative bias becomes comparatively large. This remote-cutoff or variable-Mu characteristic is desirable when a variable bias voltage is used to control the gain of the tube as in the ordinary receiver AVC circuit.

Representative curves of transconductance vs. grid bias voltage are shown in Fig. 14·14. The 6SK7 (curve *a*) and the 6SJ7 (curve *c*) are almost identical tubes except that the former is remote-cutoff and the latter is sharp-cutoff. Likewise the 6SG7 (curve *b*) and the 6SH7 (curve *d*) are almost identical except that the cutoff of the former is semiremote and that of the latter is sharp. Of the two sharp-cutoff tubes the 6SH7 cuts off at a considerably less negative grid voltage than does the 6SJ7: in fact it has probably the sharpest cutoff of any pentode listed.

Sharp-cutoff pentodes are listed in Table 19 and remote- and semi-remote-cutoff pentodes in Table 20, in order of decreasing transconduc-

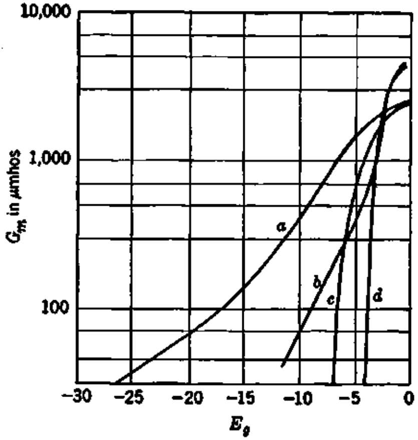

FIG. 14·14.—Cutoff characteristics of typical r-f pentodes. (*a*) 6SK7, remote cutoff; (*b*) 6SG7, semiremote cutoff; (*c*) 6SJ7, sharp cutoff; (*d*) 6SH7, sharp cutoff.

tance in each case. For many applications it is desirable to have as high a transconductance as possible, but in probably the majority of applications a more important quantity is the figure of merit of the tube, or the ratio of transconductance to interelectrode capacitance. In such applications as video amplifiers or wideband i-f amplifiers the gain for a given bandwidth will be exactly proportional to the figure of merit in such circuits as a shunt-peaked video amplifier, and approximately proportional in other circuits. Table 18 lists the figures of merit of many of the tubes of Table 19 and some from Table 20.

Types marked * in Table 18 are acorn, miniature, or subminiature construction. Those marked ** are of some special construction, such as the 713A and 717A precursors of the 6AK5, which had similar electrode structures and very small bulbs but standard bases. It will be noted that most of the types with figures of merit over 400 are of miniature, subminiature, acorn, or special construction. The only "standard-sized" tubes with high figures of merit are the 6AC7 and 6AC7W and the British types VR91, VR91A, and EF50. It may also be noted that most of the tubes in the table with figures of merit over 300 are of the sharp-cutoff type, a few are semiremote-cutoff, and none is remote-cutoff. The

TABLE 18.—FIGURES OF MERIT OF R-F AMPLIFIERS

Type	Figure of merit	Cutoff
A4444C*	920	SR
6AK5*	745	S
6AG5*	600	S
CK604A*	580	S
713A**	575	S
6AC7, 6AC7W	560	S
6AS6*	500	S
384A**	500	S
6AU6*, A4464*	495	S
717A**	495	S
VR91, VR91A, EF50	465	S
385A**	445	S
6BA6*, 12BA6*	440	SR
6AJ5*	435	S
7V7	390	S
6AB7	385	SR
7W7, 14W7	350	S
6SH7, 6SH7GT, 12SH7, 12SH7GT	315	S
1205	315	S
7R7, 14R7	310	SR
6SG7, 6SG7GT, 12SG7GT	305	SR
956*	280	R
9003*	280	R
954*	220	S
9001*	210	S
6SK7, 12SK7, 7A7, 14A7	155	R
6SJ7, 6SJ7Y, 12SJ7	125	S

last two groups in the table, as represented by the 6SK7 and 6SJ7, are typical of modern "general purpose" remote-cutoff and sharp-cutoff pentodes in which a high figure of merit was not one of the design objectives.

A high figure of merit should not be taken as an indication of the value of a given type for all applications, however, since other desirable characteristics may be sacrificed to obtain this figure. The types with a high figure of merit are usually of close-spaced construction and therefore frequently show greater variation in characteristics than more conventional types. It may be noted from Table 19 that many of the types with high transconductances are tested with resistor bias. Under these conditions the deviations from the normal or "bogie" values of essential characteristics for a representative group of tubes will be only about half as great as if the test were made with fixed bias. This effect was illustrated for the 7F8 triode in Fig. 14·12. For audio-frequency applications, especially at low power levels, tubes with high transconductances may not be desirable. One manufacturer states that the 6AC7 and 6SH7 are generally unsuitable for such uses because trouble may be encountered from heater hum unless a d-c heater supply is used.

The tubes listed in Group 19-1 have the highest transconductance of any pentodes of similar size. For this reason they have been extensively used in radar equipment as video and i-f amplifiers, as multivibrators when a fast rise and fall are desired, and for various other applications. Their figure of merit, while higher than those of any other standard-sized tubes, is less than those of some of the newer miniature and subminiature tubes. The 1851 is the parent of the other tubes of the group and may be considered obsolescent.

Group 19-2 includes three similar British tubes, which are included because they have some interesting features and because they were used in some equipment intended for joint British-American use during the war. At least two of them, the EF50 and the VR91A, were manufactured in this country. They have values of transconductance exceeded only by the tubes of the previous group and by the developmental types A4481A (19-27) and A4485 (19-28) and by two of the developmental types of Table 20. They have fairly good g3 control characteristics, a feature that will be discussed later in connection with the 6AS6.

The three types in Group 19-3 are roughly the loctal equivalents of the types in Group 19-8. They are also the nearest loctal equivalents to the tubes of Group 19-1, but differ considerably from both groups in construction and characteristics. The 7V7, 7W7, and 14W7 are actually hexodes, but since g2 and g3 are internally connected and function as a single screen grid they are usually considered as pentodes. The 7W7 and 14W7 have two separate cathode pins to permit the isolation of input and output circuits in high-frequency amplifiers. These types also have specifications on the g4 (suppressor grid) cutoff characteristics, as discussed later. The 1231 (19-4) and the 7G7/1232 (19-9) are predecessors of the types in Group 19-3 and may be considered obsolescent.

Groups 5, 6, and 7 of Table 19 list three similar high-transconductance miniature pentodes, the 6AU6, 6AK5, and 6AG5. All have approximately the same transconductance, but the 6AK5 has the highest figure of merit of any high-production type.[1] It is more uniform than most high-transconductance tubes; note that the test conditions specify fixed bias. The input and output capacitance limits are also much tighter than for any comparable type. The maximum grid current is very low,

[1] G. T. Ford, "Characteristics of Vacuum Tubes for Radar Intermediate Frequency Amplifiers," *Bell System Tech. Jour.*, **25**, 385–407 (July 1946).

Table 19.—Sharp-cutoff Pentodes

Group	Type	Ef, V	If, A	Maximum ratings: Eb, Vdc	Ec2, Vdc	Pp, W	Pg2, W	Ehk, Vdc	Test conditions: Eb, Vdc	Ec2, Vdc	Ec1, Vdc	Ib, mAdc	Ic2, mAdc	gm, µmhos	Cutoff char.: Ec1, Vdc	Ic1, µAdc max.	Limits of essential characteristics: Ib, mAdc Min.	Ib, mAdc Max.	Ic2, mAdc Min.	Ic2, mAdc Max.	gm, µmhos Min.	gm, µmhos Max.	Ic1 µAdc max.	Leakage test, Ihk µAdc max.	Emission test: Eb, Vdc	Is, mAdc min.	Base	Bulb	Notes
1	6AC7	6.3	0.45	330	165	3.3	0.45	100	300	150	nn	10	2.5	9000	− 6.0	900	8.0	12.5	1.6	3.4	7000	11,000	......	20	10	40	Oct	Metal	(1)
	6AC7W																										Oct	Metal	
	6AJ7/6AC7																				7000	12,500					Oct	Metal	
	1851																										Oct, TC	Metal	
2	EF50	6.3	0.30	300	300	3.0	1.0	140	250	250	nn	10	3.0	6500	......	......	8.0	12.5	2.2	4.0	5200	7,800	−1.0	20	10	65	nn	nn	(2)
	VR91						1.7				−2						7.5	12.5					−0.5						
	VR91A										nn						8.0	12.5											
3	7V7	6.3	0.45	330	165	4.0	0.8	100	300	150	nn	10	3.9	5800	− 8.0	10 Av.	8.0	12.5	1.0	6.0	4650	6,950	−1.0	30	10	70	Loc	T-9	(3), (4)
	7W7																		0.78	6.25									
	14W7	12.6	0.225																										
4	1231	6.3	0.45	330	175	3.3	....	.	300	150	nn	10	2.5	5500	− 9.0	10	8.5	11.5	0.5	5.0	5100	6,200	−1.5	30	20	110	Loc	T-9	(5)
5	6AU6	6.3	0.30	330	165	3.3	0.7	100	250	150	−1	10.8	4.3	5200	− 6.2	10 Av.	.	....	....	....	....	......	......	..	..	...	Min	T-5½	
6	6AK5	6.3	0.175	200	155	1.85	0.55	100	120	120	−2	7.5	2.5	5000	−10.0	200	3.0	12.0	0.8	4.0	3500	6,500	−0.1	30	..	...	Min	T-5½	(3), (6), (7), (8)
7	6AG5	6.3	0.30	330	165	2.5	0.55	100	250	150	nn	7.0	2.0	5000	− 9.0	30	5.2	8.8	1.3	2.7	4000	6,000	−1.0	20	10	25	Min	T-5½	(3), (5), (6), (7)
8	6SH7	6.3	0.30	330	165	3.3	0.7	100	250	150	−1	10.8	4.0	4900	− 6.5	50	8.2	13.4	2.0	6.0	3920	5,880	−1.0	20	20	95	Oct	Metal	(3), (6), (7), (9)
	6SH7GT																										Oct	T-9	
	6SH7L																										Oct	T-9	
	12SH7	12.6	0.15																								Oct	Metal	
	12SH7GT																										Oct	T-9	
9	7G7/1232	6.3	0.45	275	110	1.7	0.3	100	250	100	−2	6.0	2.0	4500	− 7.0	100	4.2	8.4	0.4	3.2	3700	5,600	−1.5	20	20	110	Loc	T-9	
10	713A	6.3	0.175	200	130	.	.	100	120	120	2	7.5	2.4	3900	−10.0	100	3.0	12.0	0.8	4.0	2700	5,200	−0.1	30	...	...	Oct	Spec	(3), (6)
	717A																												

11	6AS6	6.3	0.175	200	155	1.85	0.85	100	120	120	−2	5.7	3.0	3500	−10.0	100	2.5	9.0	....	6.0	2500	4,500	−0.2	20	..	...	Min	T-5½	(8), (10)
12	VR116 (Br.)	6.3	0.63	250	200	....	....	...	200	200	−4	6.7	...	3350	......	......	...	....	....	....	....	......	......	..	..	...	nn	ńn	(11)
13	7L7	6.3	0.30	330	140	1.65	0.33	100	250	100	−1.5	4.5	1.5	3100	− 5.0	100	2.9	6.3	0.3	2.4	2550	3,850	−1.0	20	20	70	Loc	T-9	
14	6AJ5	6.3	0.175	200	155	1.85	0.55	100	28	28	nn	2.9	1.0	2700	− 5.0	50	1.8	4.0	0.1	2.0	2000	3,500	−0.25	20	..	.	Min	T-5½	(3), (6), (8)
15	384A	6.3	0.15	275	130	1.85	0.55	100	120	120	−2	5.0	1.7	2500	−10.0	200	2.0	8.0	..	3.5	1700	3,300	−0.20	20	..	...	None	Spec	
	385A					....																					Oct, TC	Spec	
16	310A	10.0	0.315	275	180	2.5	0.4	150	135	135	−3	5.6	1.5	1875	−12.0	50	3.7	7.5	0.5	2.5	1500	2,250	−0.5	20	..	..	6, TC	ST-12	
	328A	7.5	0.422																										
	6SJ7																										Oct	Metal	
	6SJ7GT	6.3	0.30																								Oct	T-9	
17	6SJ7Y			330	140	2.8	0.7	100	250	100	−3	3.0	0.8	1650	−10.0	30	2.0	4.0	0.4	1.2	1325	1,975	−0.5	20	30	60	Oct	Metal	
	12SJ7	12.6	0.15																								Oct	Metal	
	12SJ7GT																										Oct	T-9	
18	14C7	12.6	0.15	330	110	1.0	0.1	100	250	100	−3	2.2	0.7	1575	− 8.5	30	1.5	3.0	0.1	1.1	1300	1,950	−0.5	20	30	40	Loc	T-9	
19	954	6.3	0.15	275	110	1.0	0.55	90	250	100	−3	2.0	0.7	1400	−10.0	25	1.0	3.0	0.3	1.25	1000	1,800	−1.0	20	15	20	Ac	Ac	(7)
	9001																		0.3	1.1							Min	T-5½	(3), (7)
20	7C7	6.3	0.15	330	110	1.0	0.1	100	250	100	−3	2.0	0.5	1300	−8.5	30	1.4	2.8	0.1	0.8	1050	1,600	−0.5	20	30	60	Loc	T-9	
21	77	6.3	0.30	330	110	0.8	0.11	...	250	100	−3	2.3	0.5	1250	−8.0	30	1.5	3.1	0.3	0.8	1025	1,475	−0.5	20	30	45	6, TC	ST-12	
	6J7																										Oct, TC	Metal	
	6J7G			330	140	0.8	0.11	100							− 8.0	30	1.3	2.9	0.2	1.0	1000	1,450					Oct, TC	ST-12	
	6J6GT																										Oct, TC	T-9	
	6C6	6.3	0.30												− 8.0	25											6, TC	ST-12	
22	1620			275	110				250	100	−3	2.0	0.5	1225									−0.5	20	30	45	Oct, TC	Metal	(1), (21)
	1603				200	....	....	...							......	...	...	....	....	....	....	....					6, TC	ST-12	
	12J7GT	12.6	0.15	330	140										− 8.0	30											Oct, TC	T-9	
	57	2.5	1.00	275	110	0.8	0.11	100							− 7.5	30	1.3	2.9	0.2	1.0	1000	1,450					6, TC	ST-12	
	6W7G	6.3	0.15	330	110	0.55	0.11								− 8.0	30											Oct, TC	ST-12	

TABLE 19.—SHARP-CUTOFF PENTODES.—(*Continued*)

Group	Type	Ef, V	If, A	Maximum ratings					Test conditions						Cutoff char.		Limits of essential characteristics						Ic1 μAdc max.	Leakage test, Ihk μAdc max.	Emission test		Base	Bulb	Notes
				Eb, Vdc	Ec2, Vdc	Pp, W	Pg2, W	Ehk, Vdc	Eb, Vdc	Ec2, Vdc	Ec1, Vdc	Ib, mAdc	Ic2, mAdc	gm, μmhos	Ec1, Vdc	Ic1, μAdc max.	Ib, mAdc Min.	Ib, mAdc Max.	Ic2, mAdc Min.	Ic2, mAdc Max.	gm, μmhos Min.	gm, μmhos Max.			Eb, Vdc	Is, mAdc min.			
	Developmental types																												
23	SD828A	6.3	0.15	330	165	2.25	0.7	300	200	150	−1	6.7	2.0	2950	−10.0 −20.0	20 2	4.5	9.0	1.2	2.8	2200	3,700	−0.2	20	10	....	SM	T-3	(13)
24	SD828E	Similar to SD828A but has higher gm and grid lead out the top.																									SM	T-3	
25	CK602	6.3	0.20	Similar to 6AK5 and CK604A but has double-ended construction and integral g2 to k bypass condenser.																							SM	......	
26	CK604A	6.3	0.20	200	155	1.85	0.55	100	120	120	−2	7.5	2.5	5000	−12.0	10 Av.	....	.....	....	....	....	......	......	..	..	.	SM	T-4½	(14)
27	A4481A	6.3	0.30	Similar to miniature type A4485; gm = 8500 μmhos.																							Ac	Ac	
28	A4485	6.3	0.30	Similar to acorn type A4481A; gm = 8500 μmhos.																							Min	T-5½	
29	A4464	12.6	0.15	Identical with 6AU6 (Group 5 above) except for heater ratings.																							Min	T-5½	
30	1205 (SD673D)	6.3	0.30	...	...	....	....	...	300	150	nn	6.5	2.0	3100	......	......	....	.....	....	....	....	......	......	..	...	....	Loc	T-9	(3), (15)

NOTES: For leakage test Ehk = 100 Vdc except for SD828A, for which it is 300 Vdc. For emission test Eb = Ec1 = Ec2 = suppressor grid voltage for all types which have separate suppressor-grid lead: for other types the suppressor voltage is naturally zero with respect to the cathode. All tubes in this table are heater-type. Suppressor grids are brought out to a separate pin except as denoted by Note (6).

(1) Under "test conditions," Ec1 is obtained from 160-ohm cathode resistor. The 6AC7W is a ruggedized 6AC7; the 6AJ7/6AC7 has a ring contact for direct grounding of the shell and has specifications for g3 cutoff; Ec1 = −3 Vdc, Ec3 = −150 Vdc, Ib = 150 μAdc max.

(2) The EF50, VR91, and VR91A are British tubes but the EF50 and VR91A have been manufactured in this country. All three have a glass bulb covered by a metal shell and a British 9-pin locking base. Under "test conditions," Ecl is obtained from a 150-ohm cathode resistor in the cases of the EF-50 and the VR91A. All three have specifications for g3 cutoff; Ec3 = −60 Vdc, Ib = 0 min, 2.0 μAdc max.

(3) Has two cathode connections for high-frequency applications.

(4) These types have 4 grids, but g2 and g3 are internally connected and function as a screen grid; g4 is the suppressor grid. The 7V7 does not have the second cathode connection. All have specifications for g4 cutoff; Ec4 = −70 Vdc, Ib = 200 μAdc max and (except for the 7V7) gm = 50 μmhos max. Under "test conditions," Ec1 is obtained from 160-ohm cathode resistor.

(5) Under "test conditions," Ec1 is obtained from 200-ohm cathode resistor.

(6) Suppressor grid is internally connected to cathode.

(7) Useful as an amplifier up to approximately 400 Mc/sec.

(8) Maximum rated Ik = 20 mAdc.

(9) The 6SH7L differs from the 6SH7GT only in its Cgp and in being 0.32 in. shorter. For the cutoff test, Eb = Ec2 = 150 Vdc, Ec1 = −6.5 Vdc, "Ib" in table = total Ik. For the Ic1 max test Ec1 = −1.5 Vdc.

(10) Has specifications for g3 cutoff; Ec3 = −15 Vdc, Ib = 20 μAdc max. Also has specifications for g3-p transconductance of 400 to 1400 μmhos for Ec3 = −3 Vdc.

(11) Has a sharp g3 cutoff characteristic; Ec1 = −3 Vdc, Ec3 = −7.5 Vdc, Ib = 200 μAdc Av. British Mazda octal base. This is a British tube and is included in this table because it and the 6AS6 are the only types available with a sharp g3 cutoff.

(12) The 1620 is a nonmicrophonic 6J7; the 1603 is essentially a 6C6 with very low noise and microphonic output; both types are intended primarily for low-level audio-frequency applications.

(13) For leakage test Ehk = 300 Vdc. Has specifications for g3 cutoff; Ec3 = −50 Vdc, Ib = 20 μAdc max. For Ic1 max test Ec1 = −2 Vdc.

(14) This type has an external metallic shielding coating, connected to a separate lead. Maximum rated Ik = 12 mAdc.

(15) For applications at frequencies up to 200 Mc/sec.

Table 19a

Interelectrode capacitances (sharp-cutoff pentodes)

Type	Cin, μμf Min.	Cin, μμf Max.	Cout, μμf Min.	Cout, μμf Max.	Cgp, μμf, max.
6AC7 6AC7W 6AJ7/6AC7	8.8	13.2	3.5	6.5	0.015
1851	8.4	12.6	3.7	6.7	0.015
EF50 VR91 VR91A	7.0	9.5	4.8	6.5	0.007
7V7	7.5	11.5	4.5	8.5	0.004
7W7 14W7	7.5	11.5	5.0	9.0	0.0025
1231	6.5	10.5	4.8	8.2	0.015
6AU6	5.5 Av.		5.0 Av.		0.0035
6AK5	3.4	4.4	2.45	3.25	0.020
6AG5	5.2	7.8	1.3	2.3	0.025
6SH7 6SH7L 12SH7	6.8	10.2	4.9	9.1	0.003
6SH7GT 12SH7GT	6.8	10.2	4.9	9.1	0.004
7G6/1232	6.8	11.2	5.3	8.7	0.007
7L7	6.4	9.6	4.5	8.5	0.010

Type	Cin, μμf Min.	Cin, μμf Max.	Cout, μμf Min.	Cout, μμf Max.	Cgp, μμf max.
310A 328A	4.7	7.1	11.0	19.0	0.013
6SJ7 6SJ7Y 12SJ7	4.9	7.1	5.2	8.8	0.005
6SJ7GT 12SJ7GT	5.7	8.3	5.6	9.4	0.005
14C7	4.7	7.5	4.8	8.2	0.007
7C7	4.5	6.5	4.7	8.3	0.007
6J7	5.6	8.4	8.4	15.6	0.005
6J7GT 12J7GT	3.6	6.2	8.4	15.6	0.005
6C6	4.0	6.0	4.6	8.4	0.007
1620	7.0 Av.		12.0 Av.		0.005
1603	4.6 Av.		6.5 Av.		0.007
57	4.3	5.7	5.6	7.4	0.007
6W7G	3.5	6.7	6.0	11.0	0.007
CK604A	5.0 Av.		3.6 Av.		0.030
1205 (SD673D)	5.4 Av.		4.4 Av.		0.003

Type	Cgk, μμf Min.	Cgk, μμf Max.	Cpk, μμf Min.	Cpk, μμf Max.	Cgp, μμf max.
713A	3.8	4.8	2.1	2.9	0.020
717A	4.3	5.3	2.7	3.5	0.025
6AS6	3.5	4.5	2.6	3.4	0.020
6AJ5	3.6	4.6	1.6	2.4	0.020
384A	2.4	3.4	1.7	2.5	0.030
385A	2.7	3.7	2.0	2.8	0.030
954	2.0	4.0	2.0	4.0	0.009
9001	2.9	4.3	2.1	3.9	0.010
77	4.1	5.3	9.7	12.3	0.007
6J7G	4.0	6.6	8.4	15.6	0.007

probably due in part to the use of a gold-plated grid. It is the most difficult to manufacture and the highest-priced of the three, and requires the least heater power. The 6AG5, while having a figure of merit about 20 per cent lower than that of the 6AK5, has the advantages of a higher plate-voltage rating, a higher plate dissipation, and a sharper cutoff. Both have two cathode connections for the isolation of input and output circuits. The 6AU6 was not produced in quantity until after the war, and was intended primarily for FM and television receivers and for general-purpose applications. Although its transconductance is about the same as that of the other two, it is obtained at the expense of considerably higher plate and screen currents. Unlike the other two, the 6AU6 does not have two cathode connections. The 6AK5 is perhaps the most widely used miniature tube in radar equipment, finding applications in high-frequency, wideband i-f, and video amplifiers, as a multivibrator or switch tube, and in other uses. It is also used as a triode, and occasionally even as a diode. The 6AG5 is used to a somewhat lesser extent for similar applications.

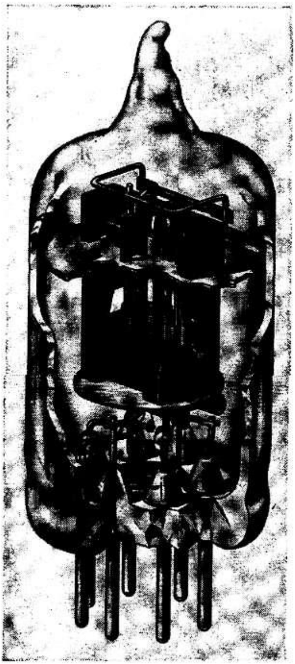

FIG. 14·15.—Miniature r-f pentode 6AS6.

The types of Group 19-8 (the 6SH7, etc.) are intended for high-frequency amplifiers. Although their transconductance and figure of merit are not so high as for the 6AC7 their other features make them preferable for such applications. These features include the use of two cathode leads, considerably less variation when operated under the same conditions, and very sharp grid cutoff characteristics. This last feature is often of advantage in multivibrator and switching applications.

The 713A and 717A of Group 19-10 are essentially earlier versions of the 6AK5 and appear to have no advantages over the latter.

The miniature 6AS6 (19-11) shown in Fig. 14·15, is essentially a 6AK5 with the suppressor grid brought out to a separate pin and with the structure so modified as to obtain a sharp g3 cutoff and comparatively high g3-to-plate transconductance. As a result the g1-to-plate transconductance is somewhat lower than that of the 6AK5, but the 6AS6 is the only American pentode with really sharp g3 cutoff characteristics. The

VR116 (19-12) has similar characteristics, and although not easily obtained in this country, is included because it is the only other type with this feature. The sharp g3 cutoff is of value in several radar applications, particularly in range unit and synchronizer circuits. Some of the pentagrid mixer and amplifier tubes can be used when good control on more than one grid is desired, and several pentodes other than the 6AS6 have g3 cutoff characteristics that may be satisfactory for certain applications. The values of grid bias for nominal plate-current cutoff for several pentodes are as follows:

Type	Group	Bias, Vdc on g3
6AS6	19-11	−15
SD828A	19-23	−50
EF50, VR91, VR91A	19-2	−60
7V7, 7W7, 14W7	19-3	−70

By comparison the 6AC7 requires a g3 voltage of −150 for nominal cutoff. More complete specifications are given in Table 19. The SD828A is a subminiature developmental type.

Of the pentagrid mixer and amplifier tubes several may be used to obtain good control from two grids. The transconductance of these types is usually less than would be desired, however. The 6L7 or 6L7G of Table 30 have g1-to-plate and g3-to-plate transconductances of about 1100 micromhos each, but g1 has remote-cutoff characteristics. The same thing is true of pentagrid converters such as the 6SA7 and 6A8 and other types of Tables 26 and 27, for which one of the two "control" grids has a remote cutoff.

The 6AJ5 (19-14) is a miniature sharp-cutoff pentode designed for operation at a plate and screen supply voltage of 28 Vdc, which can be obtained directly from the electrical system of a military airplane. Its characteristics at this low voltage are essentially the same as those of the 6AK5 at a much higher voltage. The transconductance of the 6AJ5 at 28 Vdc is about half that of the 6AK5 at 150 Vdc, but is remarkably high for operation at such a low voltage. A number of other tubes of various types have been or are being developed for 28-volt operation.

The tubes of Group 9-17 are general-purpose sharp-cutoff pentodes of modern design. They have excellent characteristics for all applications where high transconductance values are not required. The same is true of the loctal types 7C7 (19-20) and 14C7 (19-18). The types in Groups 19-21 and 19-22 have the same general characteristics but are of older design and may be considered obsolescent. The 1603 (19-22), however, is particularly suited to low-level audio stages because of its low noise and hum level.

The miniature 9001 and the acorn 954 of Group 19-19 were designed as r-f amplifiers at frequencies up to 400 Mc/sec. Although neither is of recent design, either one is probably as satisfactory as any other tube for narrow-band operation. For broadband operation such types as the 6AK5 or the 6AG5 are preferable.

Of the developmental types, the SD828A (19-23) is a subminiature pentode with characteristics suitable for general-purpose applications. Its ratings and characteristics are comparable to those of a full-sized tube, and it has a 300-volt heater-to-cathode voltage rating. It would be more generally useful if the suppressor grid were brought out. The SD828E is similar but has a higher transconductance and figure of merit. The exact values of its characteristics are not known. The CK604A is almost exactly the same as the 6AK5 but is made in a baseless T-4½ bulb. The A4481A and A4485 have higher transconductance than any other miniature or acorn tubes, and presumably also have very high figures of merit.

The characteristics of remote-cutoff and semiremote-cutoff pentodes are given in Table 20. The distinctions between these and the sharp-cutoff types have been discussed previously. In general they find their principal applications in broadcast and communications receivers where automatic gain control is used and the receivers are intended for the reception of amplitude-modulated signals. In such cases their use reduces the cross modulation encountered with signals of high intensity and in addition permits more satisfactory gain control circuits. They are little used in radar systems or in f-m receivers.

In many cases a remote- or semiremote-cutoff tube is the counterpart of one among the sharp-cutoff types, although usually the transconductance of the former will be lower at similar values of plate and screen currents. For example, the 6AB7 (20-1) is similar in construction and in many characteristics to the sharp-cutoff 6AC7. The 6SG7 (20-2) is similar to the 6SH7 (19-8), the 6BA6 (20-3) is much like the 6AU6 (19-5), and the 6SK7 (20-8) has its sharp-cutoff counterpart in the 6SJ7 (19-17).

The types in the first five groups of Table 20 are all of the semiremote-cutoff class with fairly high transconductance. Those in Group 20-2, such as the 6SG7, have two cathode leads for the isolation of input and output circuits in high-frequency operation. The 6BA6 and 12BA6 (20-3) are the only semiremote-cutoff miniature types in production.

The 7R7 and 14R7 (20-6) are loctal duo-diode pentodes with fairly high transconductance and figure of merit of the semiremote-cutoff section and are thus unique. Other duo-diode pentodes are listed in groups 20-16, 20-17, and 20-18, and the 6SF7 and 12SF7 of group 20-7 have a single diode in addition to the pentode section.

Group 15 lists remote-cutoff pentodes which have transconductances of about 2000, and which find wide application at moderate frequencies.

The 6SS7 (20-9) and the 7B7 (20-12) are similar but require only half the heater power.

The tubes in a number of the other groups of Table 20 are also much like those of Group 20-8 but are of older construction and may be considered obsolescent. They are listed in Groups 11, 14, 15, 16, 18, and 19.

The acorn 956 and the miniature 9003 (20-10) are very similar respectively, to the 954 and 9001 of Table 19. The 9003 is the only miniature remote-cutoff pentode made.

Of the developmental types the A4444C and the A4466B have the highest values of transconductance of any semiremote-cutoff pentodes listed. The 26A6 is intended for 28-volt operation like the 6AJ5, and is one of a new line of 28-volt tubes which also includes an output tube, the 26B5, a duo-diode medium-Mu triode, the 26C6, and a converter, the 26D6.