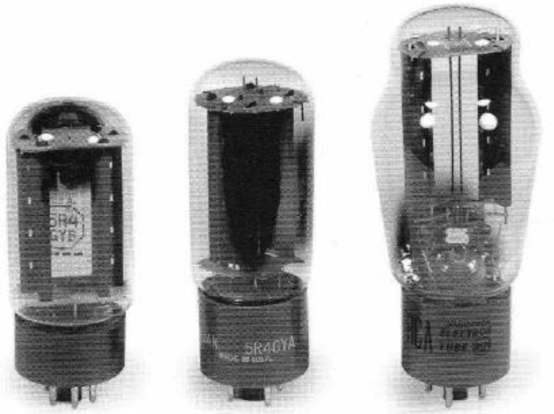


GE 5R4GYB, GE 5R4GYA, RCA 5R4G

Sylvania 5U4GB, GE 5U4GB, Sylvania 5X4G

series of radio triodes. All the RG series were apparently half-wave and had the usual 4-volt filaments and unique four-pin bases. As for post-1929 full-wave rectifiers, the Telefunken AZxx series had the greatest importance. Most had side-contact, Rimlock or "German Octal" bases, and we believe all of them had 4-volt filaments, making them unusable in modern amps.

Be warned--some pre-WWII British tubes, such as Mazda's UU6, UU7 and UU8, used the "Mazda octal" base. It looks very like the American octal, and was claimed to be compatible--however, its dimensions are slightly different. Plugging an NOS tube having such a base into a modern octal socket can result in damage to the base or the socket. Most of the types that had this base were made by Mazda and had 4-volt filaments, making them of little use today.

Note that this article does not cover 7-pin or 9-pin miniature rectifiers, nor does it cover the later novar and Compactron types or special-duty diodes. A lengthy book could also be written about larger industrial rectifiers, intended for powering transmitting tubes; we will skip over those devices, as they were used only very rarely in audio amplifiers.

3. Modern Types

Since RCA was the prime licensee for the American octal base, most of the early rectifier tubes on this base were RCA developments. The first was claimed to be the 83V, offered in 1934 and directly derived from the 83 mercury rectifier. There was also the 1-V, a vacuum type of low power capability intended for early automotive radios. Mercury or gas-filled rectifiers were also made for car radios, culminating in the cold-cathode 0Z4.

We could write another book about cold-cathode rectifiers--they were not used much outside of early radios. A rare item for collectors is the full-wave rectifier tube offered briefly by Atwater-Kent in 1927. The AK607 was a cold-cathode device for use in early B-battery eliminators. Allegedly it was made by Sylvania under exclusive contract, and was considered unreliable, replaced quickly with the UX-280. The AK607 looks like two tube grids with wire cathodes inside, obviously a "bodge." None of our textbooks mentions it, yet it is well known among tube collectors.

The 80, meanwhile, was enlarged to make the 5Z3 of 1933, in response to calls for more power capability. These early types had 4-pin bases. RCA then "octalized" the 5Z3, producing the 5Z4. The first version was copied from and resembled the "catkin" valves already being produced in England by M-OV. It had a pair of tubular metal anodes, containing vacuum and filaments. The upper ends were swaged shut, while the filament connections came through glass bead seals on the bottom. Both were mounted on an octal base and encased in an outer safety envelope of perforated metal. Other major firms produced it under license. This construction proved too costly to manufacture, so later 5Z4s were in conventional metal or ST envelopes. The 80 was subsequently made into the metal 5Y3 of 1936, then the glass 5Y3G. All of the most common 5-volt octal rectifiers appeared between 1935 and 1937.

Vacuum types lagged hot-cathode mercury rectifiers for a very good reason; mercury vapor diodes tend to have much lower forward voltage drop than vacuum diodes of the same dimensions. Plus, large lamp manufacturers (who constituted almost all the early tube makers) already had experience with making pool rectifiers and gas lamps. Mercury rectifiers are commonplace in older transmitting equipment and other high-power devices which operate at 1000v or more. This has contributed to the continued manufacture of 866As and 872As by Richardson/Cetron in the USA. Although more noisy than vacuum types, and certainly less reliable, persons desiring better performance should look into mercury-vapor rectifiers! (Oops, sorry, small ones are getting difficult to find and will never be made again, due to current severe restrictions on the commercial use of toxic mercury.)

4. Registration of Early Octal Rectifiers with EIA

(courtesy of Ludwell Sibley, Tube Collector's Association)

5Z4	7 May 1935
5Y3	6 June 1936

5X4G	26 May 1936
5W4	1 May 1936
5V4G	26 April 1936
5U4G	27 July 1936
5T4 (metal)	4 Feb 1937

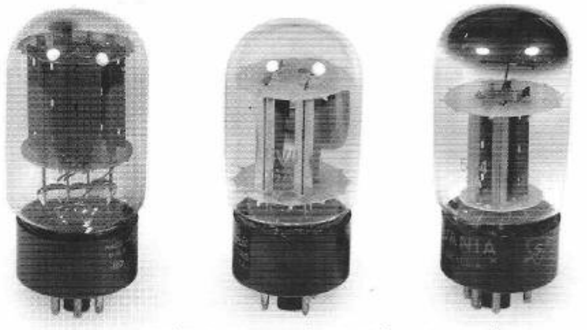
Many of the most common types appeared after WWII. The 5Y3, which started as an octal 80, became a standard for powering smaller radios and test equipment; so many variations were produced post war that we cannot possibly list them all. Among the best was the 6087, made by GE. And the pinnacle of this small rectifier type would have to be the Bendix TE-45, later called 6853. It was an even more ruggedized version of their earlier TE-22/6106, and has VERY slow warmup--more than a minute. The 6853 might be the last octal rectifier ever developed, appearing in 1963. That's late--by then, almost all industrial electronics had switched to silicon diodes. Only TV sets and very cheap table radios were still using rectifier tubes, and those were series-string types. The rare 5AZ4 was a Sylvania loktal version of the 5Y3, while the 6.3V types 7Y4 and 7Z4 were lower in ratings. Ironically, all-loktal radios were usually powered by common 5Y3s instead of loktal rectifiers.

The popular 5U4G was considered a high-power type for a long time. It was far more commonplace than any other large types--indeed, most people have little awareness of very similar rectifiers, such as the 5AS4 or 5AW4. The 5U4 went through many, many changes and versions--too many to mention. Super-premiums include the ruggedized Sylvania 5931 and the Western Electric 274A/B (more on these below). The common GE 5U4GB, with straight-sided envelope and button base, is a very tough tube and should not be discounted. It was manufactured by the tens of millions, so they must have gotten it right.

We must note here that there were two EIA pinout standards for octal rectifiers-- the most common is the original 5Z4, with anodes on pins 4 and 6 and heater/cathode on 2 and 8. This follows the EIA standards 5DA, 5L, and 5T (and the obscure 8HE), the only differences being the presence or absence of a cathode sleeve (which was always connected to pin 8). The 5Y3, 5U4, 5R4, 5V4 and most European octal types (including all GZ3x types) conformed to this system. The 5X4 and 5Y4 used the EIA base 5Q, which had anodes on 3 and 5, filament on 7 and 8--so those types are not plug-in replacements for the commoner 5T basing. Also bear in mind that 5AR4s draw only 1.9 amps on their heater, so 5U4 types cannot be substituted for them.

There are a few very obscure exceptions to this pinout scheme. The 5DJ4 is very similar to the 5U4, but has incompatible pinout 8KS. The 5CU4 is capable of higher current and lower voltage than the 5U4, and has incompatible basing 8KD. And there were several series-string rectifiers (50Y6, 117Z6, 50Y7, etc.) and damper diodes

Military Octal Rectifier Types: Sylvania 5931, RCA 5690, Raytheon 5R4WGB



RCA 5V4GA, GE 5V4GA, Sylvania 5V4GA

on octal bases. None can be used in modern or vintage amplifiers without considerable modification.

Bendix made other full-wave rectifiers, though most of them were 6X5 variants. 6X5s were popular in radio gear and are almost never seen in audio equipment. That also brings up the odd fact that rectifier tubes are still using 5-volt heaters, even though 6.3 volts has become the standard for the few receiving tubes being manufactured. Because the use of such rectifiers requires a separate well-insulated filament winding on the power transformer, and because of sheer inertia and the continued use of

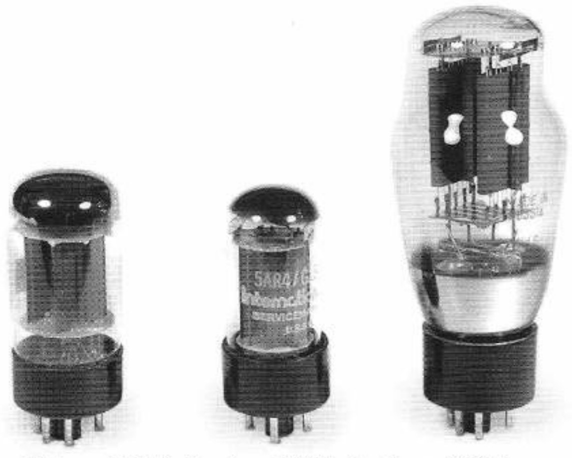
Western Electric 274A and 274B

Mullard GZ34 (wide base), Amperex GZ34, Sylvania GZ34

types 5AR4 and 5U4 in new equipment, we are stuck with 5 volts for the future. It had nothing to do with hum reduction, efficiency, or "magical sound"--it's just another historical accident.

Amperex Bugle Boy GZ34 Metal Base (1950s)

Audiophiles like to pay excessive prices for the RCA "Special Red" duotriodes 5691 and 5692. Yet those same dudes have no interest in the matching rectifier, the 5690. Because it is a very odd device, and its pinout is unique, nobody pays it any attention today. The 5690 is two totally separate half-wave rectifiers, with separate 6.3v heaters. It was extremely rugged, for use in avionics and computer systems. Unfortunately, it was replaced by silicon diodes very quickly, and saw almost no use in known equipment. It seems RCA was arrogant enough to believe they could force a nonstandard rectifier on the world. They tried this much later, with special-pinout audio tubes--and had better luck. More on this in a future VTV article.



Chinese GZ34, Russian GZ34, Svetlana 5U4G

The 5R4GY was developed at the end of WWII to address the need for a rectifier that could handle higher voltages than the 5U4G. Its peak inverse voltage rating of 2800V was almost twice that of the 5U4G. Warmup is very quick, which must be allowed for in equipment design. It was so widely used in military equipment that a super-rugged version, the 5R4WGB, appeared in 1948. This was a major product of the small firm Chatham (later absorbed by Tung-Sol), as well as Raytheon and Cetron. Uncounted millions were used in Vietnam-era American military aircraft and ships, which is why they are still easily found, even 20 years after manufacture ceased. Their rugged design and massive silicone-filled bases contributed to their common slang name: "potato mashers." 5R4WGBs are still seen in surplus shops, though I would recommend against using them in any new designs.

Western Electric made very few vacuum power rectifiers. It seems that WE's engineering staff regarded rectifiers as low importance, so they simply didn't develop very many, other than some large types for use in radio transmitters, such as the 214A, 219A and 222A. Indeed, after 1945, most Bell System telephone network equipment was powered by 5Y3s, 5U4s or 5R4WGBs bought from other firms. Not counting cold-cathode or radio detector types, the only small rectifiers WE made before 1940 were the half-wave 217A (1922), the mercury-vapor 249A-C (1929-34), 253A (1931), 301A (1937), and 314A (1937); the high-voltage 324A (1938); a few Tungar-like rectifiers for battery charging; the 6Z4-like 345A; and the 6X5-like 351A.

And finally, the only standard 5-volt versions, the much-worshipped and overpriced 274A-B (1931-35). The only difference between the A and B was the octal base on the latter. We must comment that the present street price of $1000-up for an NOS 274B is ridiculous, given that it is basically a well-made 5U4. All the other small WE types saw very little use outside the specific equipment they were designed for. WE's higher production costs must have been responsible for this situation. The only small rectifiers WE introduced after WWII were the 9-pin miniature 412A and the rare 422A (both 1948), the latter another 5U4 version which appears to be a modified 421A/5998 dual triode minus the grids. The 5998 was used in regulated power supplies as the pass device, as well as a cathode follower in early computer core memories--it is very similar to the 6AS7G. It was manufactured by Tung-Sol under contract to WE, along with 422As.

Even though British companies were on the forefront of rectifier development in the 1920s, by 1935 they had resorted to producing variations of American types on octal bases. Mullard's GZ30 was a 5Z4 replacement, the GZ31 was a 5U4, the GZ32 was an uprated 5V4, and GZ33 and GZ37 were like indirectly-heated 5U4s. I can find no evidence that a GZ35, 36, 38 or 39 were made. GZ tubes with other numbering, such as GZ40, had other base types. Currently many hi-fi amps are being equipped with surplus CV378s, which are simply British army versions of the GZ32. One sees them in Cary Audio products. Mark my words--when that small supply runs out, those excellent rectifiers will be impossible to find, and costly.

In spite of the impressions of modern audio-tube users, the 5AR4/GZ34 came very late in the game. It was introduced by Philips at the same time as the EL34, and was intended to power EL34 audio amplifiers. Unlike most previous rectifiers, it had a button base and a short envelope from the start--allowing the design to be used in low-profile hi-fi equipment. One sees an occasional mid-1950s audio amp which used a 5U4 mounted on its side; the GZ34 put an end to that.

The earliest GZ34 versions, made by Philips, Mullard and Telefunken, had the same metal base ring as the early EL34. Although branded by other manufacturers, it is probable that many of the early metal-based GZ34s were made by Philips in Holland. The later version, with the plain bakelite base, was made by Mullard in vast numbers from about 1957 until 1982. Versions with wider bakelite bases were made during the 1957-61 period. And like the EL34, both GE and Sylvania started making their own 5AR4 in 1969-70 until the late 1980s, simply because they were sick of rebranding Mullard GZ34s.

M-OV made a few octal rectifiers similar to American types, such as the U50 (like 5Z4) and U52 (indirectly heated, replaces either 5R4 or 5U4). Their GZ34 version was called U77. M-OV's famous AUDIO AMPLIFIERS booklet usually recommended a U77, U50, U52 or 5U4 to power KT66, KT77 or KT88 amps. For really large amps, they recommended full-wave bridges made of four xenon-filled GXU1s or GXU50s.

Because of all those Dynaco hi-fi amps and

GE 5AR4, Sylvania 5AR4 (USA-Made)

Metal-Based Mullard GZ34 (1950s), Genalex U52 (1960), and Russian (Svetlana) 5U4C (1950s)

FULL-WAVE RECTIFIER **GZ34**

Indirectly heated full-wave rectifier primarily intended for use in a.c. mains operated equipment.

HEATER

V_h	5.0	V
I_h	1.9	A

LIMITING VALUES

P.I.V. max.						1.5	kV
$I_{a(pk)}$ max.						750	mA
C max.						60	µF
$V_{a(r.m.s.)}$	2×300	2×350	2×400	2×450	2×500	2×550	V
Capacitor input							
I_{out} max.	250	250	250	250	200	160	mA
R_{lim} min. (per anode)	50	75	100	125	150	175	Ω
Choke input							
I_{out} max.	250	250	250	250	250	225	mA
R_{lim} min. (per anode)	0	0	0	0	0	0	Ω

TYPICAL OPERATING CONDITIONS

Capacitor input

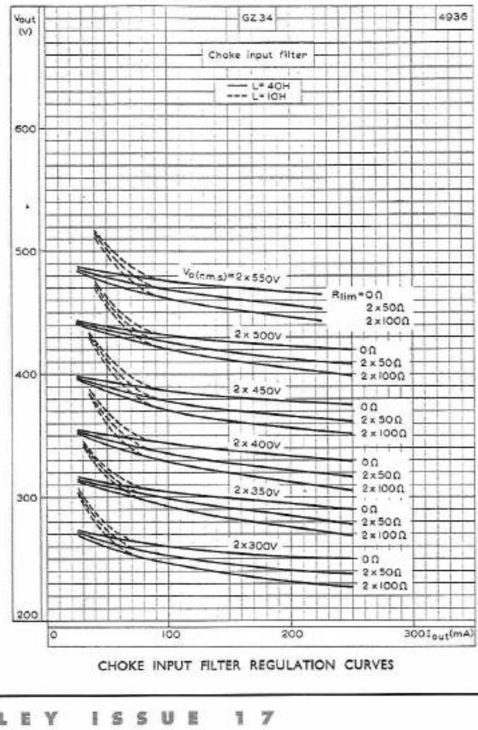
$V_{a(r.m.s.)}$ (V)	I_{out} (mA)	C (µF)	R_{lim} (per anode) (Ω)	V_{out} (V)
2×300	250	60	75	330
2×350	250	60	100	380
2×400	250	60	125	430
2×450	250	60	150	480
2×500	200	60	175	560
2×550	160	60	200	640

Choke Input

$V_{a(r.m.s.)}$ (V)	I_{out} (mA)	L (H)	R_{lim} (per anode) (Ω)	V_{out} (V)
2×300	250	10	0	250
2×350	250	10	0	290
2×400	250	10	0	330
2×450	250	10	0	375
2×500	250	10	0	420
2×550	225	10	0	465

Mullard GZ34 Electrical Specifications

Mullard GZ34 Curves



CHOKE INPUT FILTER REGULATION CURVES

Tube Rectifier Table

Type	Filament	Rated PIVmax	Iout	DC Forward drop
<150 mA DC output rating:				
5AZ4	5v, 2A	1400v	125 mA	60v
5CG4	5v, 2A	1400	125	no rating
5W4, GT	5v, 1.5A	1400	100	45
5Y3, G	5v, 2A	1400	125	60
5Y3GT	5v, 2A	1400	125	50
5Z4,GT	5v, 2A	1400	125	20
5690	6.3v, 2.4A	1120	125	17
6087	5v, 2A	1400	125	50
6106	5v, 1.7A	1550	125	60
6853	5v, 1.7A	1550	125	60
GZ30	5v, 2A	1400	125	71 max
R52	5v, 2A	700 vct max	125	no rating
U50	5v, 2A	700 vct max	120	no rating
150-250 mA DC output rating:				
5AR4/GZ34	5v, 1.9A	1500v	250 mA	30v
5AW4	5v, 3.7A	1550	250	46
5AX4GT	5v, 2.5A	1400	175	46
5R4G/GY/GA	5v, 2.0A	2800	250	67
5R4GYB	5v, 2.0A	3100	250	63
5T4	5v, 2.0A	1550	225	45
5U4G	5v, 3.0A	1550	225	44
5U4GA	5v, 3.0A	1550	250	44
5U4GB	5v, 3.0A	1550	275	50
5V4G/GA	5v, 2.0A	1400	175	25
274B	5v, 2.0A	1550	225	no rating
GZ33	5v, 2.8A	1250	250	no rating
GZ37	5v, 2.8A	1000 vct max	250	no rating
52KU	5v, 2.0A	1000 vct max	150	no rating
53KU	5v, 2.8A	1000 vct max	250	no rating
54KU	5v, 2.0A	700 vct max	250	no rating
U52	5v, 2.25A	1000 vct max	250	no rating
U54	5v, 2.8A	1000 vct max	250	no rating
>250 mA DC output rating:				
5AS4	5v, 3.0A	1550v	275 mA	50v
5AT4	5v, 5.5A	1550	800	30
5AU4	5v, 3.75A	1400	325	50
5V3	5v, 3.8A	1400	350	47
5V3A	5v, 3.0A	1550	415	42
422A	5v, 3.0A	1800	400	no rating
5931	5v, 3.0A	1700	300	47
GZ32	5v, 2.8A	1000 vct max	300	no rating
CV378	same as GZ32			

Basic Data on Full-Wave Octal Rectifiers With 5Y3-Like Basing

WARNING: You should never, ever substitute a rectifier in your amp whose filament draws more current than the rectifier the amp was designed for! Nor should you try to use a rectifier which isn't rated for the DC output current needed. If your amp uses a 5AR4, do NOT try a 5Y3, 5U4, U5x or CV378--no matter how tempting it is.

Ratings for some types can vary from one maker to another--following are believed the most commonly-seen ratings.

guitar amps that used it, manufacture of GZ34/5AR4 types continues in Russia and China, though at very low levels compared to audio output tubes. Indeed, the only other vacuum rectifiers still being made (except for a few exotic high-voltage devices) are believed to be the Svetlana 5U4G and 6D22S. The former was used in millions of pieces of Soviet electronics, while the latter was the damper diode seen in color TV sets made by Positron Electronintorg of St. Petersburg (now defunct). Only by accident are these types still available; the Svetlana-Malevishera affiliate factory which has produced them for decades is still there, though hanging by a thread.

4. Why They Can Sound Different

Firstly, we need to comment on the urban legend that the 5R4 sounds better than the 5U4 when used to power a SE tube amp. As Norm Braithwaite points out, the amp's transformer saturates less with a 5R4 rectifier than with a 5U4, because the 5R4 drops more voltage, thus passing less current (the tube's bias voltage not having been adjusted by the geniuses who did these tests)--thus, less distortion due to less saturation.

Second, because different tube manufacturers used similar-but-different cathode materials, the short-pulse emission characteristics of a given tube can be less or more than a similar type that otherwise tests the same. Full-current emission (sometimes called "charge-limit emission") is rarely given as an official rating. In the case of small octal rectifiers, it was not regarded as being important. This is usually most noticeable with guitar amps, which are often run deep into clipping and have poorly filtered plate supplies.

If you want a recommendation, we can't do that--every amplifier responds differently. However, we can give some pointers.

1) Design your power supply to be clean and well-regulated. This can be done with electronic regulators. However, we seriously question the need for this. Adequate plate-supply filter capacitance, with all amplification stages decoupled separately, will do far more for the performance

of an amp than swapping rectifier tubes. DIYers have more freedom than the buyers of commercial products, because the manufacturers of amps often try to cut corners and save money, and the most obvious way is to leave out decoupling stages.

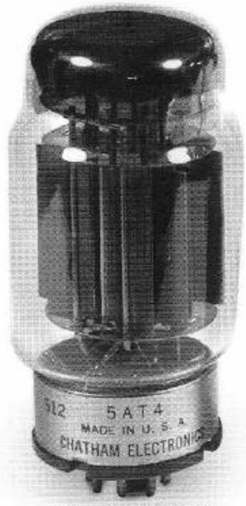
2) Single-ended Class-A tube amps can be sensitive to rectifier choice, usually for reasons such as we have already mentioned--not for good reasons, mind you. A properly designed SE triode amp should NOT be sensitive to the type of rectifier tube--and push-pull amps will tend to be even less sensitive. Class-A tube amps do not need huge quantities of filter capacitance, for much the same reasons. (Provided they are well-designed, something which is often not the case.)

3) If you are blessed with a vintage amplifier, stick to the type of tube it was designed to use. Don't experiment blindly. Due to the lower quality of modern valves (and resulting lower plate voltages being run in modern tube amps), NOS GZ34s would be strongly recommended for vintage amps such as the Dynaco Mk. III, which is very hard on rectifiers. For that matter, if you want to make your vintage amp last, get a Variac or autotransformer and set it to produce AC mains voltage 20% less than the stuff coming out of the wall socket. Yes, you will get a little less power output--but your tubes will be very, very happy, and so will the power transformer.

4) The "best" is a relative term. If you want the best rectifier tube, go with mercury vapor--provided you are willing to deal with scarcity, and the threat of mercury poisoning if a tube is broken. The best rectifier from the standpoint of ultimate performance is clearly the FRED diode, not any rectifier tube. However, if you insist on a VACUUM rectifier tube, the best performance overall probably comes from damper diodes. They are ideal for DIY, since they are cheap and plentiful.

The Ultimate Octal Rectifier--You Never Heard of It!

Our "best" rectifier isn't the 5R4WGB "potato masher" so often seen in *Sound Practices* projects; it isn't the 5931, or the red-base 5690 (which saw little use anyway), nor is it any of the Bendix Red Bank types. Chatham (later Tung-Sol), Raytheon and Hytron produced a tube that makes ALL other octal vacuum rectifiers look wimpy. The number is 5AT4. You want more figures? OK, the 5AT4 was introduced in 1959, and was very rarely used. We have only seen it in high-current regulated power supplies. Production ceased in the 1980s. It is capable of supplying up to 550 volts at 800 mA, into a choke-fed filter. Is that enough for you? And it would be amusing to watch some idiot buy a Chatham 5AT4 (it is indeed very scarce and hard to find) and plug the tube into their 5AR4 socket and get a nice cloud of smoke, as the power transformer burns up. Alas, the 5AT4's heater draws 5.5 amps at 5 volts. Don't say you weren't warned!



Chatham 5AT4

5. Exit

As a final note, we must warn that the vacuum rectifier might not be a viable product for the future. Very few modern guitar amps use tube rectifiers; those that do are currently going through surplus stock of the Svetlana 5Y4S/5U4G, which is the only such tube still made. At least three new 5AR4 versions have been made in the last 10 years, two by Sovtek/Reflector and one from China. It is hoped that the current Reflector version, called GZ34EH, will prove to be decently reliable, because in a few years it may be the only game in town--though there is rumored to be a very good GZ34 coming soon from JJ Electronic. Very few high-end audio manufacturers use rectifier tubes, since they are convinced that semiconductor diodes give superior performance (silicon certainly is much more economical). Persons who feel that the vacuum rectifier is a valid product, and who want it to stick around for a while, should support what manufacturing still exists; and not call dealer after dealer, frantically looking for NOS bargains. Soon there won't be any.

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Our thanks to Norm Braithwaite, John Eckland, Bill Condon, Igor Popov and Ludwell Sibley for their invaluable assistance in researching this subject. Igor provided a copy of the rare WIRELESS WORLD Valve Directory which made it possible to examine pre-war British rectifier data.