When I Think Back...

by Neville Williams

The rise and fall of thermionic valves or 'tubes' – 2

The initial 25-odd years of the present century saw 'wireless' emerge as a practical means of communication and entertainment, but widespread demand from about 1930 onwards triggered a virtual explosion in technology, requiring valves far removed from the lamp-like diodes and triodes of Fleming and De Forest.

In the late 1920's came a big industry push to get away from the tedium batteries, wherever possible, and to produce receivers for full AC mains operation. It called for a complete revolution in valve design and manufacture.

It was easy enough to rectify and filter AC for the HT (plate) supply, but not for the valve filaments. Nor could the filaments of existing valves be operated satisfactorily from AC. Several volts of AC applied across the filament would be much the same as having a large 50Hz voltage superimposed on the grid/filament bias. It would be treated and amplified by the valve as an input signal.

While the effect could be cancelled, in part, by suitably centre-tapping and earthing the filament supply, the temperature of the delicate valve filament – and therefore its emission – would still vary over each individual half-cycle. This caused the electron stream to be modulated at 100Hz, creating an intolerable hum in the loudspeaker.

AC powered valves

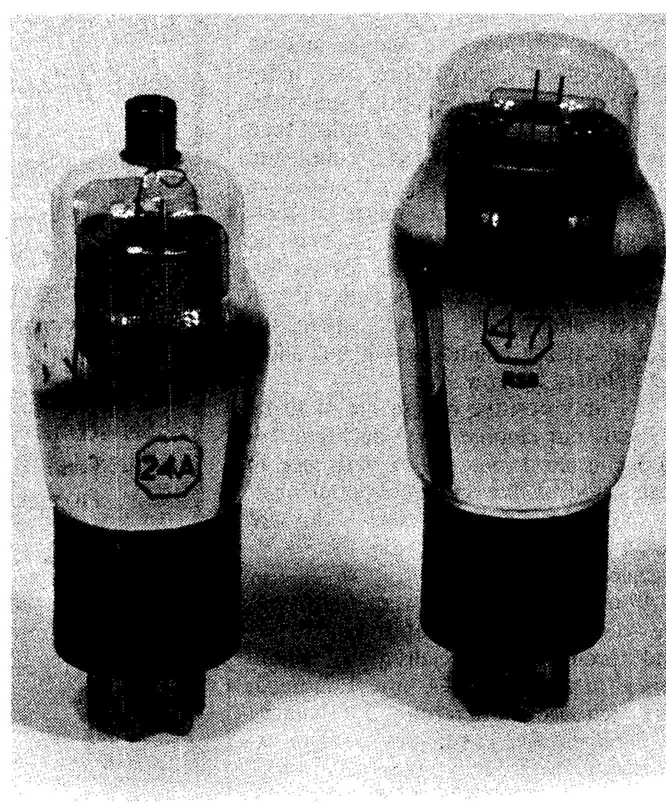
The industry's initial response to this problem, circa 1927, was a notably conservative one: the American type 26, a triode much like the traditional 01-A except that it was fitted with a rugged filament rated at 1.5V and 1.05A. The purpose of the low operating voltage was to minimise signal injection into the grid/filament circuit; secondly, the stout, heavy current filament was meant to exhibit high thermal inertia, thereby reducing the temperature variation over each successive half-cycle.

With critical setting of the earthed centre-tap on the transformer filament winding, the 26 triode worked reasonably well in all stages of typical contemporary TRF (tuned radio frequency) receivers – except the detector, where the hum problem demanded a more radical solution.

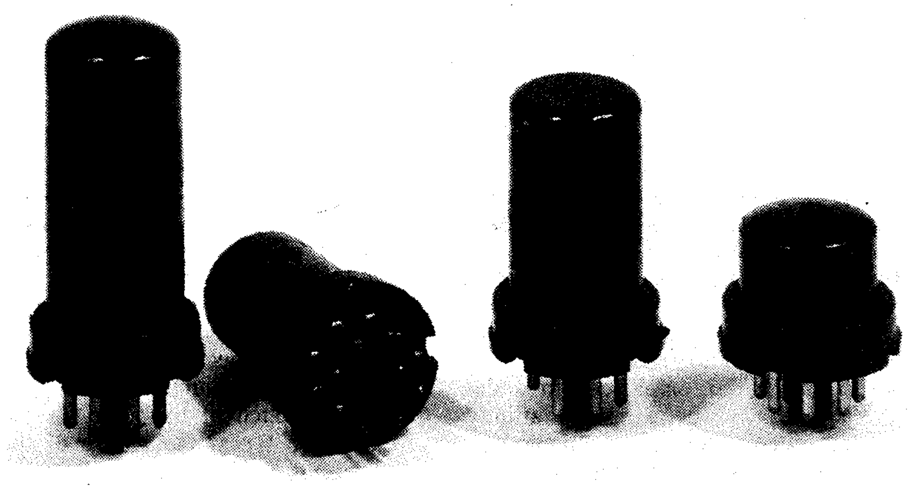
Fortunately one was forthcoming, in the form of the indirectly heated cathode: a thin metal tube coated externally with an emissive oxide (Fig.3). A separate heater element was located inside the cathode sleeve, but electrically insulated from it by ceramic end bushes or sleeve or by a heat tolerant slag (e.g., aluminium silicate).

In fact, the idea had been patented by Messrs Freeman and Wade of Westinghouse as early as 1921, but not commercially developed. It was taken up later by the McCullough and Kellogg companies in the US circa 1925, and used to produce double-ended, indirectly heated replacements for the 01-A.

The idea was that a set of the new McCullough/Kellogg tubes could be plugged directly into an existing battery set, their original function being preserved by having the cathode sleeve connected internally to the now otherwise dormant filament pins. The new heater, brought out through the top of the bulb was energised via a supplementary overhead harness, fed from an external low voltage 'filament' transform-



Two classic AC powered receiving valves from the late 1920's – early 1930's era. At left is a 24-A RF amplifier tetrode, with a type 47 power output tetrode at right. Together with the type 80 rectifier, they formed the heart of many Australian radio sets of that era.



Examples of the first 'all metal' 8-pin octal based valves which first appeared in America around 1935. Later octal valves had a glass envelope.

er. By also substituting a commercial 'eliminator' for the B-batteries, the old battery set could thus become all-AC operated!

Taking the longer view and faced with the need for an indirectly heated detector to go with their type 26 triodes, RCA produced the 27 – an otherwise traditional triode with insulated cathode and a 2.5V/1.75A heater – fitting it with a 5-pin plug-in base. In so doing, they signalled the mass production of AC mains powered receivers.

Fairly obviously, the evolution of valves to this point had hinged largely on the incandescent filament/cathode and the problem of ensuring a sufficiently copious electron stream for a manageable current drain. Less lamp-like constructional methods had also emerged but, in terms of amplification factor, transconductance and plate resistance, triodes like the 26 and 27 (226 and 227) differed little from the original 201.

Tetrodes & pentodes

Apart from the line-up of 26's as RF and AF amplifiers and a 27 as detector, the initial wave of mains powered receivers likewise departed little from the circuit concepts that had previously been developed around battery valves. But that phase was shortlived, and the only receivers of that type I encountered personally were those that subsequently accumulated in the factory basement as trade-ins.

In the present climate of nostalgia, those hum-prone 26/27 discards would probably be worth a lot more now than they were then!

Designers soon made it clear that they preferred indirectly heated valves for all sockets and, what's more, that they'd had enough of the chronic instability of triodes as RF amplifiers – a by-product of their high internal grid-plate capacitance.

Research in both Europe and America had produced battery valves with an extra grid, placed between the control grid and the plate. Operated at a fixed positive potential somewhat below that on the plate and bypassed to ground, it served as a passive electrostatic shield between the two critical electrodes. (See Figs. 4 and 5). By bringing one of the connections – normally the grid – out through the top of the bulb, the capacitance between the connecting leads could also be minimised, reducing the overall grid-plate capacitance by a hundred times or more.

Reacting to this demand, valve manufacturers released a number of mains type 'screen-grid' (or *tetrode*) RF amplifiers, the best known in Australia being probably the 24-A (or 224) released in 1929 as a companion valve of the 27 triode. Two years later, the 'variable-mu' type 35 (235) appeared, with very similar characteristics except that a variable-pitch control grid made it possible to adjust the signal amplification over a very wide range by varying the bias (Fig.5).

From type to type

During 1931/32 a flood of locally produced mains receivers was released onto the Australian market using one or two type 35 valves as RF amplifiers, a 24 or 27 as detector, a 45 power output triode or a 47 power tetrode, and an 80 rectifier. About the same time, however, a highly practical version of the superheterodyne type circuit began to gain favour and appeared on the market with a comparable valve complement.

By the time I entered the industry in early 1933, those valves, too, had been superseded and replaced by the '50' series, also using 2.5V heaters but fitted with slimmer envelopes and boasting improved performance. At the same

TETRODES, PENTODES & DIODE TRIODES

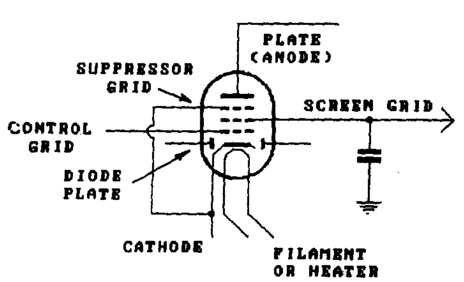


Fig.4: A basic triode, as in Fig.2, contains a filament or a heater/cathode combination, a control grid and a plate (or anode). In a screen-grid (or tetrode) valve, an extra grid is placed between the control grid and plate. Operated at a fixed positive potential, usually somewhat lower than the plate, and bypassed to earth, it serves as a passive electrostatic shield between grid and plate. By thus reducing the grid/plate capacitance, it makes it possible to achieve high gain in RF amplifier stages without instability and oscillation.

The signal handling capability of a tetrode valve can be further improved by inserting a *suppressor* grid between the screen and plate. Operated at earth or cathode potential, it prevents slow-moving 'secondary' electrons, dislodged from the plate by the incoming 'primary' electron stream, from being attracted back to the screen.

Some multi-element valves also provide one or two small diode plates, adjacent to one end of the filament or cathode sleeve, so that signal detection can be provided within the same envelope, along with a signal-dependent voltage to provide automatic gain control.

Other typical multi-element valves contain twin triodes, separate triode and pentode sections, or complex electrode structures intended for specialised roles such as frequency changers in superheterodyne receivers.

time, the tetrodes had become *pentodes*, with a third 'suppressor' grid inserted between plate and screen to refine the overall dynamic characteristics (Fig.5).

As it happened, the 2.5V series had one serious limitation: their unsuitability for use in automotive receivers – operating commonly, in those days, from 6-volt systems. RCA and others had provided for this market with the 36-39 series, but in the mid 1930's they released 6.3V versions of the 2.5V series, suitable for either mains or automotive use.

If that wasn't enough, they came up with yet further equivalents, available in both glass and all-metal construction, using the IO (international octal) base and with either 6.3V heaters, or 12.6V to suit the new generation of 12V cars.

There were parallel developments in the design of receivers for country areas. The Americans offered the 30-34 series, combining operating economy with reasonable ruggedness, but with only modest performance specifications.

The European 'golden' series boasted state-of-the-art design, with far better specifications, but quite unequal to the rigours of transport from European factories to the living rooms of Australian rural homes.

The uniquely Australian 2.0V/120mA series provided a much better combination of economy, performance and reliability and were widely used in the early 1930's for both battery and vibrator powered receivers – filling the breach until the appearance of the all-glass 1.4V miniatures.

A whole story could be written around these developments, but the long and short of it simply was that consumer radio revolved almost totally around valves.

- The status, price and presentation of a receiver depended on the number of valves: 4 – economy; 5 – standard; 6 or more – up-market.
- Having nominated the valves, a designer would reach for the data books and design the circuit accordingly.
- The age and merit of trade-in receivers was determined largely by the valve complement.
- Valves featured large in troubleshooting, with servicemen needing to carry and account for a full range of replacement types. Owners, hoping to save the cost of a service call, bought large numbers of replacement valves from radio shops.
- Light-fingered employees in radio factories showed a special affinity for valves, because of their unit value and the fact that they were readily useable or saleable.

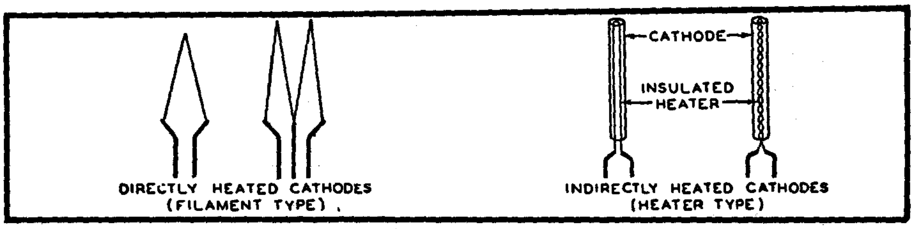


Fig.3: To minimise current drain, battery valves normally use a directly heated coated filament (left). But most mains powered valves used an indirectly heated cathode (right), to minimise hum injection into the signal path.

I must confess to considerable culture shock when I moved out of this overall environment into the AWV factory in Ashfield, Sydney – to be surrounded by thousands of valves in every stage of manufacture. A hitherto exclusive, high-tech product was suddenly revealed for what it really was – bits of wire, metal and glass, created and assembled by automatic machines and by the deft fingers of process workers, equally 'programmed' to perform specific tasks.

Valves had been produced in small numbers in Australia since the early 1920's, principally by AWA under licence to RCA. Large scale manufacture began in 1933, following the setting up of the Amalgamated Wireless Valve Company in the previous year. Philips established their own valve factory in 1936 at Hendon, SA, while STC became involved in valve manufacture in 1939, mainly to meet specific needs of the PMG's Dept (now Telecom) and, later, the Australian Defence Forces.

Valve production

AWV was still a relatively young company when I joined it in 1936. Officially, the valves were being manufactured to RCA specifications, covering such things as the number of turns and the winding pitch of the grids for the various valve types, the nature of the side rods to which they had to be peened, and how they had to be trimmed to fit the pre-punched mica support washers.

In practice, the specifications had to be amended to suit materials and production facilities available to AWV, and to effect possible economies in the context of shorter production runs.

My first job in the company was to identify such amendments from engineers' and supervisors' personal notebooks and to generate official AWV specification sheets for master filing. It was a task that, for me, dispelled much of the early mystique associated with valves.

I discovered, for example, that a 'variable-mu' or super-control characteristic could be obtained without resorting to a special variable pitch control grid (Fig.5). An aperture created by snipping specified half-turns from a standard grid would let sufficient electrons through at high bias levels, to produce much the same 'remote cut-off' characteristic!

A little further down the track, I was to become involved in the derivation and publication of valve characteristics – in those days, the technological counterpart of holy writ. As mentioned ear-

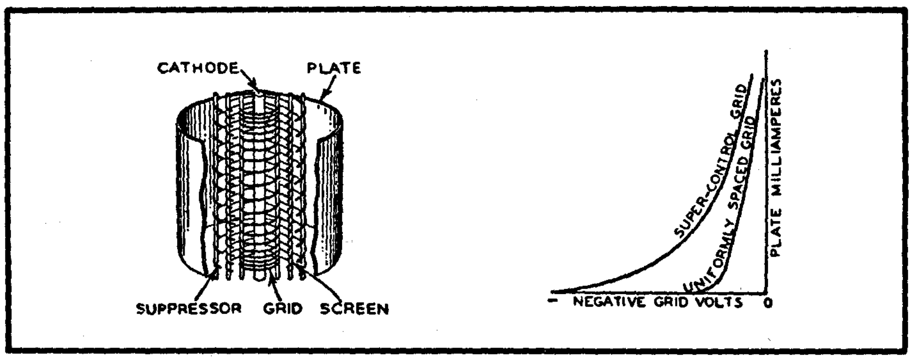


Fig.5: At left is the electrode structure inside a pentode valve. The grid winding pitch was normally uniform, but a variable gain or 'super-control' characteristic (right) was achieved by varying the control grid pitch over its length, as shown.

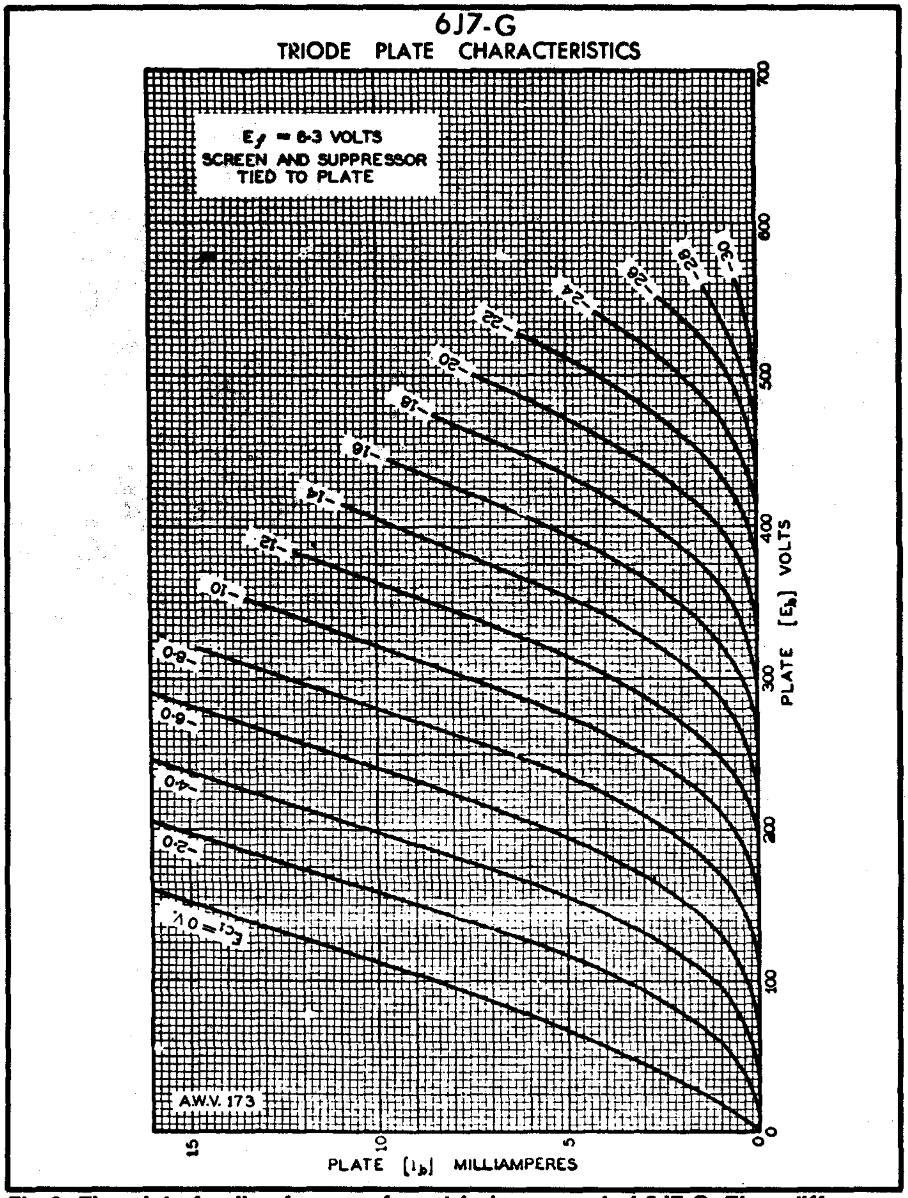


Fig.6: The plate family of curves for a triode-connected 6J7-G. They differ very slightly from earlier curves for the equivalent 6C6 triode.

lier, equipment designers, great and small, would closely study the published data, work out sums on their slide rules involving voltage, current and resistance, and generate the precise circuitry for each successive stage.

Producing valve data

To derive, verify or expand basic valve application data, the AWV lab was equipped at the time with permanent tabletop test set-ups involving adjustable heater, grid and HT supplies, each one monitored by lab-quality voltage and current meters with large, mirrored scales and housed in traditional polished, dovetailed wooden boxes.

Used also to check developmental versions and production samples for quality control, the equipment was then under the watchful eye of the late Ron Tremlett, who subsequently joined the Philips group, becoming President of the IREE (Aust) in 1964-65. (Sadly, most of the aforesaid equipment was destroyed in a major fire which gutted the AWV factory in the early '40s).

When deriving tabulated data and characteristic curves for particular types, the tests were not performed on just any valve. Like most other fabricated products, valves were/are subject to manufacturing tolerances and exhibit a spread of characteristics, not normally apparent to everyday users but certainly evident on instruments.

To derive or examine basic performance data, tests were always performed on what we described as 'bogey' valves – selected from production samples for salient characteristics near the centre of the tolerance range. This was to reduce the likelihood of predictable conflict with data already published.

For plate family curves in particular (Fig.6) the measurements were also made in a sequence, which covered low-current readings first, working progressively upwards into the higher current regions and minimising the on-time for readings above the maximum rated dissipation. The reason for so doing was to minimise structural heating and artificial ageing effects on the cathode.

In due course, the figures would be transferred to graph paper by a technical draftsman – at the relevant time the writer – and examined for graphical discontinuities, to expose possible reading errors or anomalous curves. They would also be checked against other curves and published data to ensure that there was no discrepancy in spot readings of electrode current, or with basic characteristics as deduced from the slope and position of the individual curves.

Ultimately, the curves would be inked in and published – ostensibly applicable to all valves bearing the same RMA type number. To the extent that valve data acquired a reputation for consistency, worldwide, I can only assume that the respect for standardisation and uniformity in AWV was matched in other companies working to American RMA conventions.

One other thing I remember vividly from my stint in the AWV lab: Every day or so, sample valves from each production batch would be handed to Ron Tremlett. He would document and check each one and then plug them into special life test racks, for exposure to full rated operating conditions for 1000 hours or more. Set up at one end of the lab, the heat from those racks was a bonus in winter but just the reverse during a Sydney summer.

On completion of the life test, the valves would be re-checked to ensure that they were within acceptable tolerances, and then discarded. They would later be methodically smashed, along with other test and developmental samples, so that they could be subtracted from production totals and would not attract government excise charges.

I must confess that, to an enthusiast from way back, the deliberate destruction of perfectly useable valves was sacrilege of the highest order – and a source of personal agony!

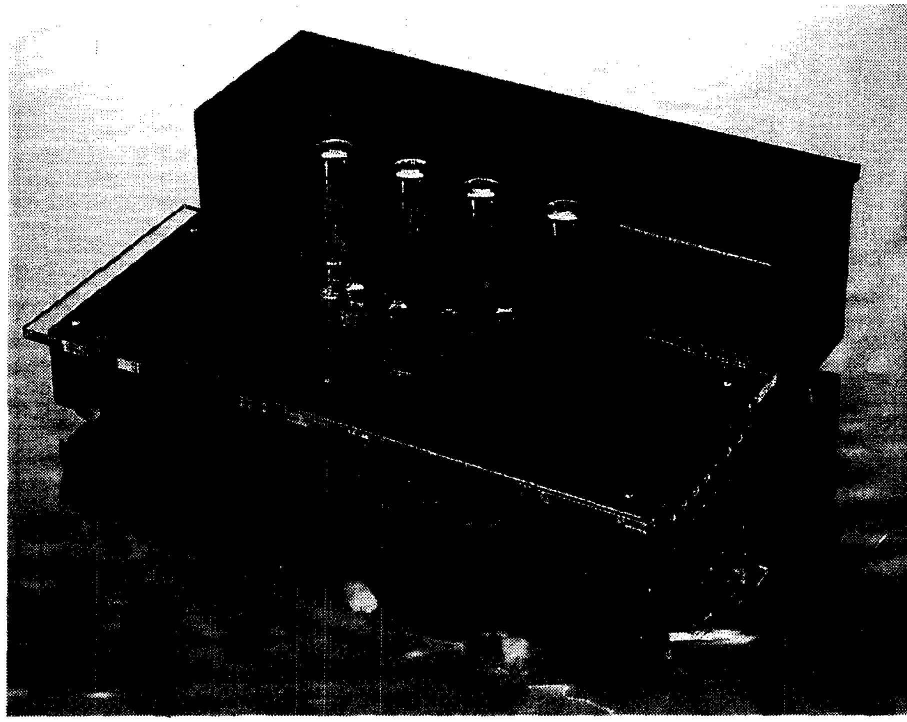
The memory of all those 'busted bottles' became even more haunting during the war that followed soon after, when new valves became a scarce commodity, especially for hobbyists.

Valves for a 'song'

But then, in the 1950's, the hobby market was suddenly flooded with a huge array of valves that became available through war disposals and stock clearance, by factories re-organising for peacetime production.

Who, from that generation, can forget cartons full of all-metal 6H6 twin diodes? Or 6N7 twin triodes? Or 6AC7 and EF50 high-gain RF pentodes? And 6L6 'beam-power' output valves, or their ubiquitous 807 glass equivalents for use in transmitters?

It was around that time that I bought several type 800 UHF power triodes for next to nothing, and built around them a 100W 6-metre UHF transmitter. It called for a 1000V plate supply, but that was no great hassle, assuming one could find a high voltage ex-disposals transformer. Type 866 mercury vapour rectifiers and their high vacuum counterparts like the 836 were also available very cheaply.



This new Audio Innovations Series 500 integrated amplifier features valves in its output stages, operating under pure class-A conditions and offering 25 watts output per channel.

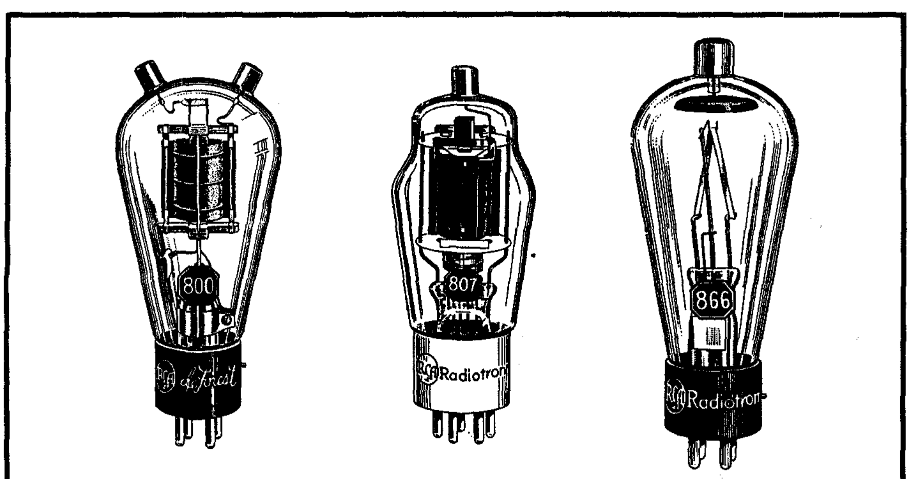
For the HF bands, I built a transmitter around the magnificent old 803 RF power pentode, capable of 150-odd watts output in class-C telephony or 200 watts CW. I bought a couple of them ex-disposals for a proverbial 'song'. For two songs and a bit of luck, in those days, one could pick up its up-dated successor the 813.

And, of course, there were the cathode-ray tubes, intended originally as spares for radar and other military equipment. Because these took up a lot of valuable storage space, dealers were glad to get rid of them. As some readers may recall, many of them ended up in home-built oscilloscopes, along with a fistful of ex-disposals valves. Others provided small green pictures in our first rudimentary TV sets, built in the mid 1950's.

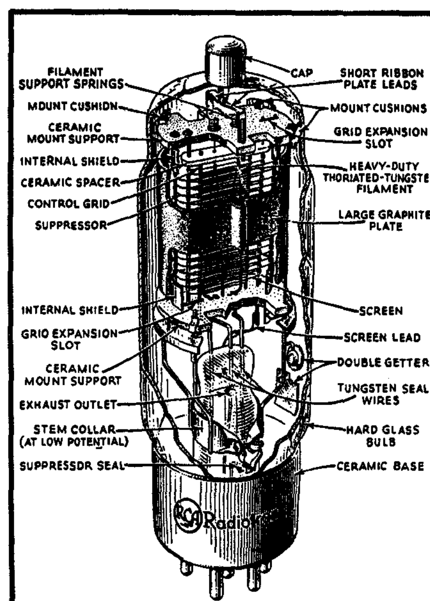
It took quite a while for enthusiasts to absorb the flood of war surplus valves, but they gradually gave way to new, high-tech postwar types, many of them developed for TV and high quality audio service.

Then, quite suddenly – or so it seemed – it was all over. Thermionic valves and their attendant circuitry had given way to solid-state devices, and to digital and other complex signal processing techniques which they made possible.

Within a few years, new radio and TV sets, amplifiers and just about everything else had been 'transistorised'. So had the handyman projects in technical journals such as *Electronics Australia*. Valve factories closed down, valves dis-



Left to right: The type 800 HF power triode, used by amateurs in 50MHz transmitters; the 807, virtually a 6L6 beam power tetrode redesigned for RF service; and the 866 high voltage mercury vapour rectifier.



STRUCTURE OF TRANSMITTING PENTODE RCA-803

The writer's postwar transmitter was based around an 803 power pentode, with a solid graphite plate.

appeared from dealers' shelves and servicemen had to learn a whole new bag of solid-state tricks.

My last glimpse (as a visitor) inside the AWV factory was in the early 1970s, at Rydalmere, a few kilometres from the original site at Ashfield.

As before, rows of process workers were busily spot welding the electrode assemblies ready for the 'sealex' machines. Elsewhere, the power valve section was assembling transmitting type valves for broadcast and TV stations and other professional users.

With an eye to the future, another smaller line was producing small-signal transistors, against the day when they might – just might – make inroads into the valve industry.

At the rear of the building, they were assembling monochrome picture tubes while, at the same time, taking the first tentative steps towards a possible changeover to colour.

Add the machine shop and metal working facilities, the applications lab, the bulk store and despatch facilities, the management office and staff amenities and it was quite a setup.

But just a few weeks after publication of my article on Fritz Langford-Smith I received a letter from Frank Stroud, who joined AWV in 1934 on the original Ashfield site and retired from Rydalmere at the other end of his career. He framed and answered the question as to what finally happened to that hitherto successful enterprise.

With the cessation of valve and picture tube manufacture, he said, a tiny remnant of the Company ended up as the Special Valve Production Section of AWA.

Involving just seven or eight people from the original power valve section, they were occupied in building and rebuilding transmitting valves such as the 4CX5000 and 4CX10000, the 3J160 and 6166A. They would cut them open, fit new filaments, replace and/or realign the grids, then re-seal and re-exhaust them for a further period of service.

But, according to Frank, even that operation is no more, having been closed down at the end of 1989. For Frank, the only tangible reminders of the old Valve Company are in the personalities of valve engineers Jack Shaw, Don Frazer and Doug Sutherland – whom he sees from time to time at meetings of AWAVA - the AWA Veterans Association. (Current President is Reg Vine, who can be contacted on (02) 624 8974)

In truth, however, valves are remembered and mourned on a far wider plane than those whose whole career once depended on their manufacture.

Out there in suburbia is an enthusiast cult devoted to the reclamation of old-time valve radios, which yesterday's hobbyists and servicemen still find sufficiently large and comprehensible to work on.

Like steam locos, valve radios seem to have a personality all their own!

What's more, cult members find common cause with certain hifi buffs who insist, rightly or wrongly, that valve amplifiers exhibit an essential 'sweetness' of tone that they believe has thus far eluded their more highly specified solid-state successors.

Even as I write, a brochure has landed on my table extolling the virtues of a new Audio Innovations Series 500 amplifier. The valves on which it depends, according to the letter, are ranged in a semi-circle on top of the unit, for all to behold!

For me, that turns the clock back over 60 years, to when my father laboriously replaced the bakelite panel on the family wireless with plate glass, allowing all and sundry to contemplate the shiny valves inside while they enjoyed the program.