'TECHNICAL SHORTS'

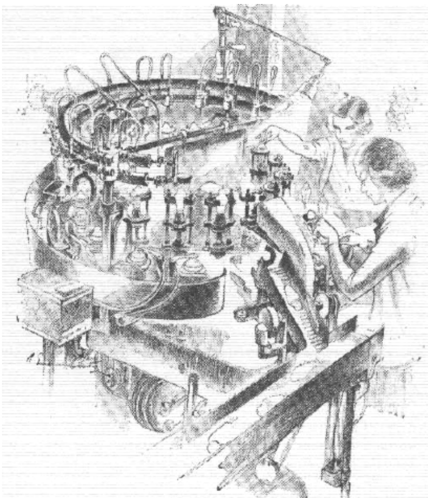
by Gerry O'Hara, G8GUH

'TECHNICAL SHORTS' is a series of (fairly) short articles prepared for the Eddystone User Group (EUG) website, each focussing on a technical issue of relevance in repairing, restoring or using Eddystone valve radios. However, much of the content is also applicable to non-Eddystone valve receivers. The articles are the author's personal opinion, based on his experience and are meant to be of interest or help to the novice or hobbyist – they are not meant to be a definitive or exhaustive treatise on the topic under discussion…. References are provided for those wishing to explore the subjects discussed in more depth. The author encourages feedback and discussion on any topic covered through the EUG forum.

Valve Lore

Introduction

Valves, or 'tubes' as our across-the-pond cousins refer to them as, are the physical embodiment of the thermionic technology that reigned as King in the land of electronics for well over half a century. Even today, another half a century on, this technology is still used in certain niches of everyday life – until the last few years, almost all computer monitors used the cathode-ray tube, as did TV sets (I still have 3 CRT monitors and 5 CRT TV's working in my home!) and much high-power transmitting equipment still uses valves, as do the 'esoteric' hi-fi audio and high-end guitar amplifier manufacturers – the latter not because of a quaint desire to be 'retro' or to sate the 'golden-ears' of folks that can apparently hear the difference between two types of wire or phono plugs (the 'better sounding' ones of course costing ten times more than the other), but because valves really do perform better (sound better) than their solid-state counterparts – this is certainly true for the desirable distortion produced by overdriven valve guitar amplifiers in rock music. I even own two modern 'Valvetronix' VOX guitar 'modelling' amplifiers that are all solid-state apart from a single 12AX7 (ECC83) duo-triode in an application far removed from anything its 1940's designers ever anticipated – a 'valve-reactor' power stage that includes the two triodes in push-pull configuration with their own 'output' transformer, driven (or deliberately over-driven) in a controlled way to 'model' the characteristics of the particular amplifier being copied by integrated circuit pre-amps and then driving a solid-state output stage 'for that authentic valve tone' – maybe weird, but they actually do sound great (check out http://www.voxamps.co.uk/).

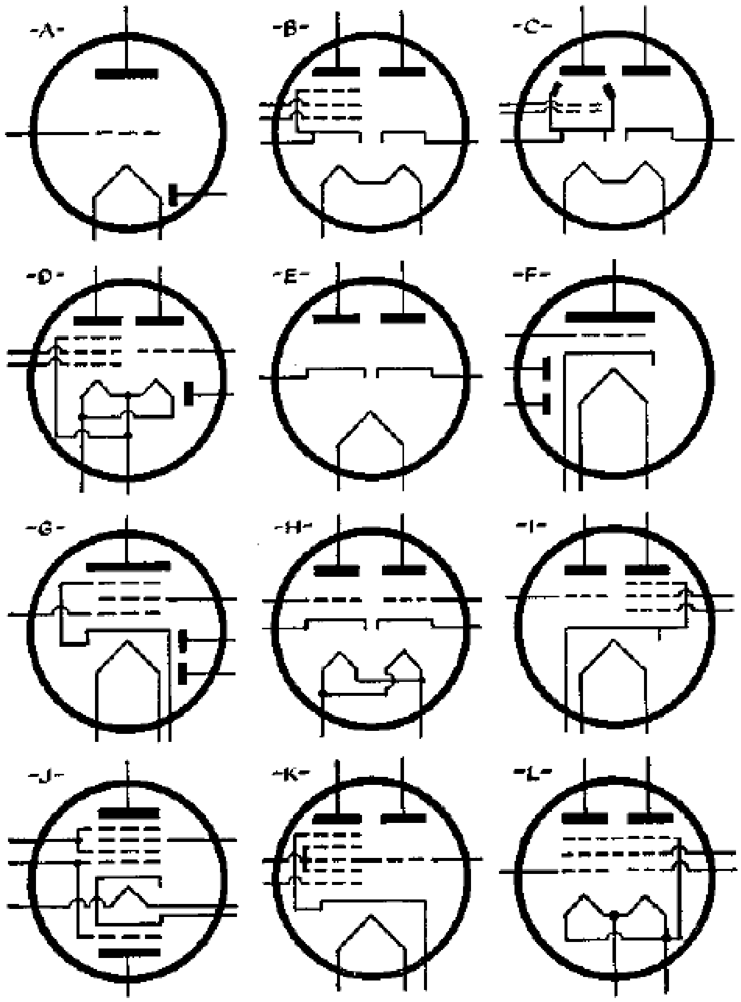

RCA's 'Sealex' machine C. 1940

I first became interested in radio and electronics in the late-1960's, very near the end of the valve's reign as King. At that time most portable equipment, especially simple broadcast band-only radio sets, had become fully 'transistorised', but quite a lot of equipment had not: I owned an 'Ultra' reel-to-reel tape recorder from around 1968 that was 'valved' as was my first stereo and, at least in part, my first TV). When I took my City and Guilds exam, I had to learn both technologies, which I think stood me in good stead overall; a bit like the transition to metric measurements – I am fortunate that I can use either with relative ease as I first learned one at school and then the other. The amateur radio world was in a similar state of transition at that time, as was the manufacturer of our favourite marque of receiver: Eddystone had built their prototype transistor portable in 1961 and their first commercial transistorized receiver as a solid-state version of the S.940 receiver, the S.960, in 1962, but it was not until 1973 that the final valve sets rolled out of the Bath Tub (the professional S.830 series) – apparently not because of lack of demand for these sets or outmoded specifications, but because some of the actual parts used in their construction were becoming hard to obtain! There was also a lot of 'hybrid' valve/solid state equipment about in both consumer and amateur markets at that time, usually using the 'three-legged fuses' and even analogue integrated circuits, in the small-signal stages, with valves in transmitter driver/output stages, eg. 6146B's, 8873's or even pre-WWII designed 813's and 807's at HF, and QQV03-20A's, 4CX250B's or 3CX1500's at VHF (many of these valves are still in use today in these applications), and in video, line output and voltage booster stages of TV sets, eg. PL509, PL802 and PY88 (these fading from use in the 1980's as solid state devices were finally able to handle these applications reliably).

So I thought a little discussion on the evolution and use of the radio receiver valve would be useful and of interest - especially for anyone not familiar with the technology, along with a summary of some popular valve types and their uses in Eddystone sets. This 'Short' does not (and could not) do more than scratch the surface of this fascinating subject however, but it does provide a 'taster' and the still-interested reader is recommended to look up some of the many selected references and web-based resources provided throughout and at the end of the article.

Valve History and the Basics…

I am fairly certain that folks reading this will know how the thermionic valve works and how it was developed, at least in general terms, and I therefore do not intend to repeat this information herein. For those that need a quick refresher, read the relevant chapters of the RSGB Radio Communication Handbook (Editions up to and including #6), or the valve section of Colin Seymour's website (http://www.cjseymour.plus.com/elec/valves/valves.htm) that provides a fairly succinct outline of valve types, characteristic curves and the like and is well worth a visit by the novice valve-equipment enthusiast. The detailed development and history can also be researched on some of the specialist valve technology and museum web sites, eg. http://www.valve-museum.org which has an excellent series of articles.



Typical multiunit tubes. (A) 1 diode, 1 triode (1H5–GT/G). (B) 1 diode, 1 pentode (12A7). (C) 1 diode, 1 beam power (117P7–GT). (D) 1 diode, 1 triode, 1 pentode (1D8–GT). (E) 2 diodes (6H6). (F) 2 diodes, 1 triode (6SQ7). (G) 2 diodes, 1 pentode (6B7). (H) 2 triodes (6SL7). (I) 1 triode, 1 pentode (6F7). (J) 1 triode, 1 hexode (6K8). (K) 1 triode, 1 heptode (6J8–G). (L) 2 pentodes (1E7–G).

The 'Boom Years' (1930's and WWII)

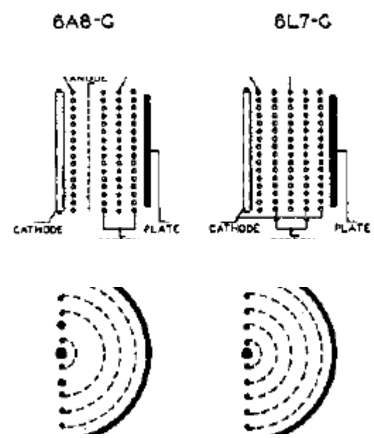
Development of the valve in the late 1920's and 1930's was extremely rapid, taking the ubiquitous triode amplifier valve types used in the early to mid-1920's through the tetrode, pentode, hexode, heptode and pentagrid mixers, triode-hexode mixer-oscillator (see discussion on mixer valves below), duo-diode triodes, cathode-ray tubes etc, and peaked with meeting the needs of high-performance, ruggedized and specialized equipment to satisfy the military in WWII (eg. klystrons and magnetrons), funded by military-driven R&D budgets: indeed, virtually all the main radio receiver valve genres, bases and envelope types in use today were developed in this era.

Why So Many Types And Why Do Some use Number and Some Both Number And Letter Identifiers?

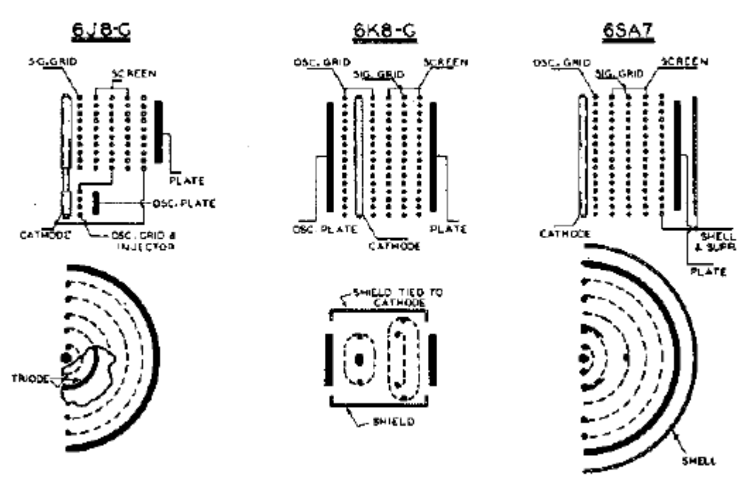
The basic valve genres and variations of them as used in the majority of radios are noted above, ie. only about a dozen or so when HT rectifier diodes are included as well as diode-pentodes and ‘magic-eye’ types, so why are there literally thousands of valve types and why so many numbers and mixtures of numbers and letters used to identify them? Good questions: here are some short answers (easily a whole chapter of a book for a full explanation!):

- Evolutionary changes or new sub-classes of valves, eg. the evolution of the ‘frequency converter’ and ‘mixer’ valves includes the following:
    - Triode pentode (eg. 6F7), using a triode oscillator and pentode mixer, performance of this type is poor on the shortwave bands, leading to the;
    - Pentagrid ‘converter’, ie. mixer-oscillator (eg. 6A8), better than the triode pentode valve, but performance is poor above 15MHz. Another type of pentagrid, the 6SA7 uses an entirely different form of construction and the grids are used for different purposes than in the 6A8 type;
    - Pentagrid mixer (eg. 6L7), using a separate oscillator (eg. 6C4), generally provided satisfactory performance throughout the shortwave bands (under the correct bias conditions);
    - Triode-Heptode, eg. the 6J8, which is equivalent to a 6L7 with an oscillator triode incorporated into the same envelope. The low noise performance of the 6J8 made this valve popular in receivers without an RF amplifier stage;
    - Triode-Hexode, eg. 6K8 or (as used in the S.640) was a very popular ‘converter’ valve in the 1940’s through early 1950’s, it having significant conversion gain throughout the HF bands.

  The constructional differences of the above are described in the *Radiotron Designers Handbook* and a brief clip from this is shown right for reference;



Vertical and horizontal cross-sections through a variety of mixer and mixer-oscillator valve constructions (Radiotron Designer’s Handbook, 3rd Ed.)



- There are many variations of the basic types developed to meet different circuit conditions/applications.

A 'small signal' pentode, eg. 6BA6 would not perform in a 'power' application, such as an audio output stage, where a 6AQ5 would perform well. Likewise, the element design and inter-electrode spacing needed for a well-performing audio valve would not be suited to a high-power RF application. Also, the need to automatically or 'remotely' adjust the gain of a valve led to the development of variable-mu, or 'remote cut-off' valves (eg. the 6BA6).

- The heater voltage and current draw was a major factor in producing different 'lines' of basically the same valve type, this was to suite moving from battery-powered sets in the 1920's through AC-powered sets in the 1930's, through series-connected requirements of AC/DC sets, 6v and 12v car radios etc. So, heater voltages included 1v, 2v, 3v, 4,, 5v, 6v. 12v, 19v, 35v, 50v and even 117v variations of many valve designs, eg, 12AT6 and 6AT6, the first part of the valve identifier being the voltage in the 'standard' US naming protocol – see below.
- Different envelope types usually added a suffix, eg, G for glass envelope of a previously metal envelope valve, or GT for 'glass tubular' (see below);
- Different countries and/or manufacturers adopted different naming standards/systems (some with a meaning, some arbitrary – see below); and
- The militaries in different countries adopted their own bespoke systems, eg a JAN (Joint-Army-Navy) type JAN-6005 (usually only the number is used as a reference, eg. 6005) is the US military nomenclature equivalent of a 6AQ5 or EL90. 'Ruggedized' versions of the JAN types added W as a suffix, again – see below. Once in the 'military arena', valve specifications often warped further in the quest to attain more reliability over simply being more rugged. This spawned many more sub-types of essentially the same valve, eg. the lowly duo-diode 6AL5 became the JAN-6AL5, then after post-war 'ruggedization', it morphed into the JAN-6AL5W, then into the JAN-5726 following efforts of the US military 'reliable tube program' in the 1950's, which finally (I think) evolved into the JAN-6097 after further minor specification changes to suit military requirements.

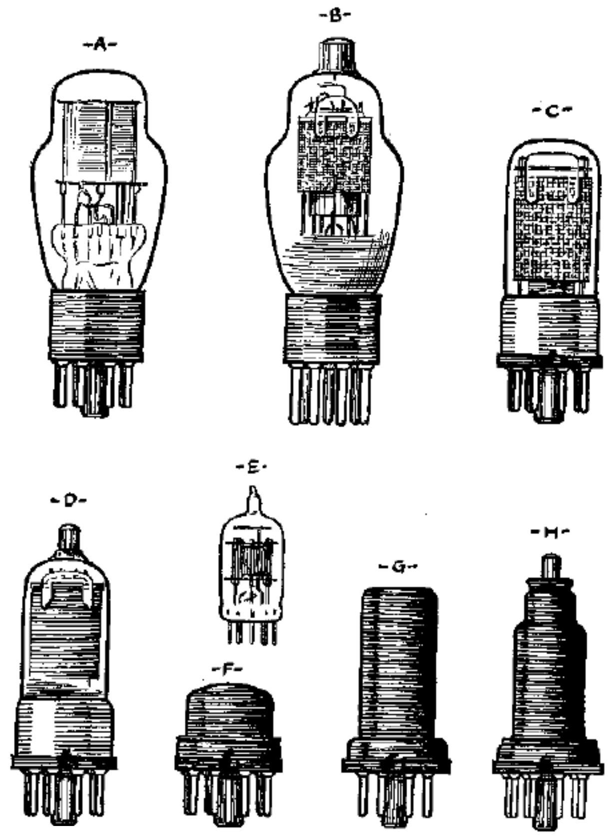
Valve Bases

More electrodes meant there was a need for more pins on the valve base, or to add a top cap(s), the latter usually being the grid connection. Bases therefore went from four pins (two for the heater, one for the grid and another for the anode), to five, six, seven, eight, nine… culminating in the 12 pin 'Compactron' in the 1960's and multiple pin cathode ray tube types, each with several variations of spacing, pin diameters, insulating material (eg. moulded phenolic plastic, Paxolin wafer, ceramic), provision for attaching a screen, provision of a securing system (eg. locking pin in 'Loctal' types), forced-air ventilation etc.

I have included a diagram of common base types at the end of this article for reference.

Envelope Material and Styles

By far the most common envelope material is glass, however, metal and metal/glass combination envelopes were introduced in the mid-1930’s. The general tendency through the years was to reduce the size of the envelope where possible: the biggest change was when metal-glass bonding and construction techniques allowed the development of valves with the element connections to form the external (base) pins themselves, rather than having a separate base attached to wires passing through the glass envelope, as in the Octal and earlier styles. This first manifested itself in the production of the ‘Loctal’ type valves, which also incorporated a locking central spigot held in a base attached to the glass envelope, however, this trend eventually led to the development of the ‘miniature’ B7, B8 and B9 series of valves which occupied an order of magnitude less volume than their Octal and Loctal predecessors.

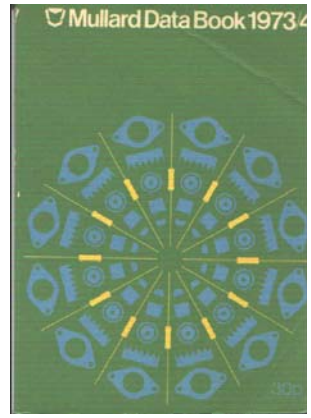


Types of tube envelopes. (A) Glass, pear-shaped, no grid cap. (B) Glass, pear-shaped, grid cap. (C) Glass, tubular, no grid cap. (D) Glass, tubular, grid cap. (E) Glass, miniature. (F) Metal, type 6H6 tube. (G) Metal, no grid cap. (H) Metal, grid cap.

There are a number of standard envelope shapes and these are summarized in the diagram, above.

Valve Naming Protocols

As briefly noted above, there are several protocols for valve ‘names’, ‘numbers’ or ‘designations’:



- In the UK and Europe, the 'Pro-Electron' type nomenclature system was widely used, the logic behind this is as follows:
  - The first letter indicates heater voltage or current (though not very logically): A is 4v, C is 200mA, D is 0.5 to 1.5v, E is 6.3v, K is 2v, G is 5v, P is 300mA, U is 100mA.
  - The second and subsequent letters indicate the general class of valve: A is a single diode, B is a duo-diode, C is a triode, D is a power output triode, E is a tetrode, F is a pentode, L is a power output tetrode or pentode, H is a hexode or heptode (hexode-type), K is an octode or heptode (octode type), M is a tuning indicator, Y is a half wave rectifier and Z is a full wave rectifier.
  - The first number indicates the type of base: eg. 2 is a B10B or B8G, 3 is an octal, 4 is a B8A, 5 is a B9D, 8 is a B9A (noval) and 9 is a B7G.
  - Remaining numbers indicate a particular design or development.

For example, an ECC83 is a duo-triode with a 6.3v (actually 12v, centre-tapped) heater, having a B9A base, and an EC90 is a small-signal triode with a 6.3v heater and B7G base. There are some exceptions to this system, however, and some European manufacturers went their own merry way – this is not too much concern to Eddystone enthusiasts though.

- In the US, around 1933 the main valve manufacturers introduced a naming system (the EIA specification registration system) that was meant to provide more descriptive and logical names for valves. The intent behind this was again to identify some important features of the valve in its designated name, here using three or four groups of numbers and letters:
  - Group 1: Approximate filament voltage: 0 is cold-cathode, 1 is 1.4 to 2.0v, 2 is 2.5v, 3 is 3.8v, 5 is 5v etc, through to 117v.
  - Group 2: Informational letters, U,V, W, X, Y and Z are used for rectifiers, and S may be included to indicate that the control grid is connected to a base pin of a valve formerly fitted with a grid top cap.
  - Group 3: A single number from 1 to12 that indicates the number of useful elements connected to terminals (pins) on the valve base, including a shield element, if present.
  - Group 4: Additional information, usually letters, eg. special characteristics such as quick-heating version of another valve designation, or envelope style, eg. G for glass version of an earlier metal type, GT is a smaller, tubular glass envelope, ST indicates a 'dome-shaped' bulb whereas an S denotes a sprayed-on shield. A 'W' was added to many US military valves to identify 'ruggedized' versions, designed to withstand specified levels of vibration or shock through specially designed internal elements, insulators and support structures (it should be noted that the W does not

necessarily equate to higher performance or longer life of a valve under normal operating conditions).

My own observation is that although this system usually makes sense, it often does not and there are many exceptions to the logic underlying it. For example, a 5U4G is a rectifier with a 5v heater and a glass envelope with 4 external terminations – very logical, but a 6L7 is a pentagrid mixer (6v heater, 7 external terminations), whereas a 6SL7 is a twin triode (again with 6v heater, 7 external terminations) – somewhat illogical and rather misleading. Eddystone used many valves with US designations, so be very careful that any replacement is the correct one.

- In addition to the above, there are various military systems, both in the UK and US, as well as some other countries:
  - The UK had Army, Navy and Air Force designation systems during WWII, changing to the 'CV' number designations thereafter. Most of these are military specification versions of 'civilian' types, eg. an ARP34 is the Army equivalent of an EF39 (as used in the S.504, S.556 and S.604), a CV3883 is equivalent to the EAF42 (eg. as used in the S.740), and a CV1862 is equivalent to a 6AQ5 (eg. as used in the S.830 series).
  - The US military numbering system, starting with '5500' (why? – who knows), eg. a 6005 is equivalent to the 6AQ5, and a 5749 is equivalent to the ubiquitous 6BA6 RF pentode, the latter as used in many Eddystone sets as RF and IF amplifiers. The 'W' designation may also be added (see notes above).

  Eddystones sets were used frequently by the military and many 'professional' grade sets, eg. S.830, S.850 and S.770 series may still have military specification valves fitted.

This may all be very confusing for the novice valve radio collector or user, though in practice the number of radio valve types you will actually come across, especially if you stick with Eddystones, is relatively small: the best way to become familiar is to obtain one or two equivalent books, obtainable from several sources, including http://tubesandmore.com, and visit museum sites on the web, eg. http://www.valve-museum.org. Also, reference to the 'Valves Used in Eddystone Receivers' and 'Suggested Alternatives For Valve Used in Eddystone Receivers' tables prepared by Tor Marthinsen, both downloadable from the EUG website, should help.

The 'Golden Years' (1946 into the early-1960's)

By the end of WWII, development of the major valve-types used in domestic and communication receivers had virtually been completed, including multiple valves in a single envelope. Thereafter, radio valve development concentrated on:

- Re-packaging existing element structures and designs into miniature envelope styles;
- Relatively minor improvements to existing designs;

- Higher-power applications;
- Sub-miniature ‘acorn’ and ‘nuvistor’ envelope styles for specialist applications, eg. VHF, UHF and microwave applications;
- Higher frequency/power magnetrons, travelling wave tubes etc;
- Specialist applications, eg. beam FM detector valves such as the 6BN6;
- Integration of several valves into a single ‘Compactron’ device, aimed at reducing the number of valves in a particular application: the swansong of the radio valve era. A table showing some of the valve development ‘milestones’ is shown below (from Tomer, 1960).

UNIVERSAL ERA	1907—DeForest's “Audion”
	1920—1.1-volt battery radios; 5.0-volt pure tungsten; 00 and 01 tube types
	1923—5.0-volt thoriated tungsten; 01A, 01AA tube types
	1925—3.3-volt thoriated tungsten; X99 tube types
	1927—2.5-volt indirectly-heated cathode tubes; screen-grid tetrode
	1928—2.0-volt oxide filament; 30, 32, 33, 34 tube types
	1931—6.3-volt auto sets and transformer radios
	1933—300-ma series-string radio with ballast tube
	1934—Acorn types for high frequency
	1935—Metal envelope tubes
	1938—150-ma series-string radios; GT and lock-in tubes; first miniature tubes
	1939—TV beginnings, video amplifiers developed
SPECIALIZED ERA	1941—World War II HF radio, radar, special devices
	1946—TV first-era small screens and radio tubes
	1948—Computer tube developments
	1950—TV large deflection angle scanner tubes–cascode tuner tubes
	1951—Multisection tubes for TV, series-strings with thermistors
	1954—TV series-strings, warm-up controlled heaters; TV low-voltage B+ tubes
	1956—12-volt hybrid automobile radio tubes

Eddystone started to adopt the miniature styles in 1950, quickly phasing out the Octal style with the exception of some rectifiers and voltage stabilizers.

Valves Used in Post-WWII Eddystone Radios

Eddystone were rather conservative in their use of valves, with ‘standard’ types being adopted for a variety of receivers and applications. For example, some of the valves used in receivers of the early 1950’s, eg. VR150, 5Z4G, 6BA6, were used in receivers right up to 1973.

Mid-late 1940’s Eddystone receiver designs employed Octal valves (EF39, ECH35 etc), in the S.504, S.556, S.659, S.640 and S.670 sets), with miniature types, B7G, B8A and B9G entering service in the early-1950’s in the S.680, S.740 and S.750 sets etc, though some Eddystones retained octal rectifiers (eg. GZ34) and/or stabilizer types (eg. VR150) right through to 1973. Typical valves used for various applications in Eddystone sets of this period included:

- RF amplifier: 6BA6 (pentode), ECC189 (duo-triode in cascode)

- IF amplifier: 6BA6
- Local oscillator: 6C4
- Mixer/Local oscillator: 6AJ8
- Noise Limiter: 6AL5
- Product detector/BFO: 6BE6
- First audio/AM detector: 6AT6
- Single-ended audio output: 6AQ5
- Push-pull audio output: 6AM5
- Rectifier: 5Z4G
- Voltage Stabilizer: VR150 (Octal), OA2 (B7G)

The AC/DC sets used the 'U' series (100mA heater current) equivalents of the 'E' series, eg. UAF42 instead of EAF42 (single-diode pentode). The UHF (S.770U series) used slightly more 'esoteric' valves in the front end, the 6AJ4 or 6AM4.

A list of valves used in all Eddystone receivers (as posted on the EUG web site) is appended to this article for reference.

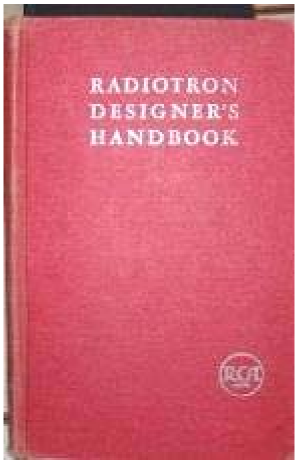
Valve Life and Failure

Valves generally have surprisingly long working lives, most 'small signal' types giving over 10,000 hours of service - some many more, provided they are operated within their design criteria – Peter Lankshear ('*Eddystone Servicing For Beginners*', Part 6, Lighthouse Issue 75, P18) reports a 6AV6 still working after 57,000 hours (over 6.5 years of continuous service: is it still working Peter?) and I have a 1936 'Airline' radio that has four of its original valves still in place and working… and I suspect one or two in some of my other radios are original fitment also. Of surprise to many is the fact that if valves are not used, they generally do not deteriorate at all - providing their physical integrity is not compromised - as the inside of the glass or metal envelope is a high-vacuum and thus protected from oxidation, moisture and other age-related environmental influences that other components suffer from. As a result, 'new-old-stock' (NOS) valve purchases usually work like new (however, be wary of used valves in new-looking boxes: many service shops and individuals were loath to chuck replaced valves out, 'just in case' they would work in another set or simply through hoarding tendencies, so they wiped the dust off them and placed them in the boxes belonging to the replacement valves. These sometimes appear are NOS or 'new-in-box (NIB) on EBay and the like, probably quite innocently – I have been bitten once by this).

It should also be noted that valves tend to exhibit the classic 'bathtub' curve of electronic component failure, with most catastrophic failures occurring after a fairly short period of use, thereafter, the valve settles down into its normal operating cycle, with fewer sudden failures, but eventually a deterioration in performance for one or more of the reasons noted below.

Having said this, of course we all know that valves do fail, develop faults or suffer from impaired performance:

- Degenerative failure: aka 'wearing out', usually a gradual deterioration in performance from the valves original specification, resulting from reduced emission, leakage of air into the valve or production of other gases in minute (but significant) quantities by other phenomena, eg. excessive heater voltage or high cathode current operating conditions (the colour of the getter is usually a give-away here – it tends to turn white in the presence of gas), spurious emissions, cathode depletion (not a real 'problem' for most post-WWI valve types as other factors usually come into play first), inter-electrode leakage, etc;
- Catastrophic failure: those that occur suddenly, without warning and cause an immediate equipment malfunction, such as an open circuit heater (most common, especially in AC/DC equipment), glass envelope or glass-metal seal failure (eg. around pins), disconnection or shorting of internal elements due to metal-fatigue, weld failure etc.; and
- Subjective faults: these can range from 'excessive' hum, microphonics or 'excessive' noise, though these effects can often be resolved by careful circuit design and construction.



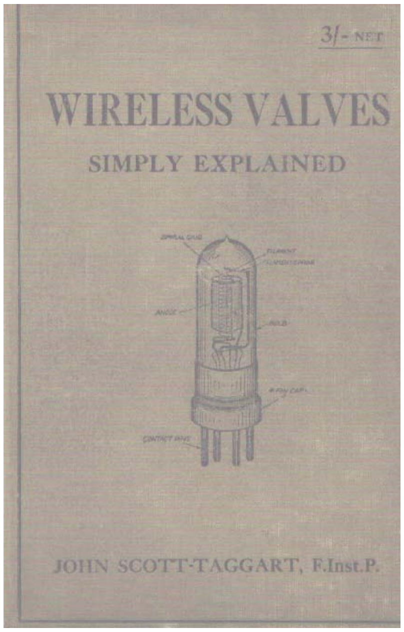
B. Tomer's, 1960 book *Getting the Most Out Of Vacuum Tubes* provides some interesting discussion on valves, including failure modes, as well as attempts to promote longer lives and to 'ruggedize' valves for applications where vibration or shock were a potential contributor to a valves demise: well worth a read if you can find a copy (try the book pages on

http://www.tubesandmore.com/ as I believe they sell a reprint). Also, F. Langford Smith's *Radiotron Designer's Handbook* is work a read for further insights.

A table summarizing some common receiver faults that may be valve-related is provided below.

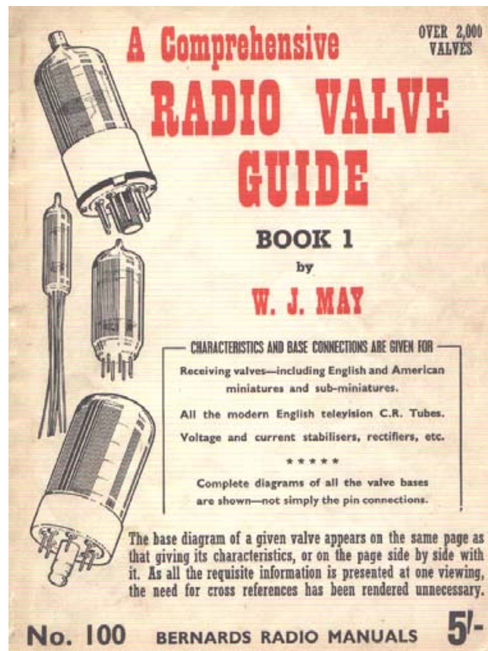
Component Characteristic	*Reference Letter**	*Troubles*
No amplification or output	*a* *b* *c*	Burned out (open) heater or filament Leads to elements broken inside envelope Leads to elements poorly soldered or not soldered to tube prongs or grid cap Short circuits between elements Short circuit between grid cap and shell of metal tube
Low amplification or output	*a* *a, d*	Low emission—overload or overaged heater or filament Low G_m—low emission; or incorrect element spacings resulting from jarring, vibration, etc. Gassy, due to leakage of air into glass or metal envelope or escape from elements Increase of effective capacitance between elements because of presence of gas or shift of elements
Distortion and hum	*a, d*	Intermittent interelement shorts due to jar or vibration Shorts or leakage between cathode and heater or between grids and other elements of frequency-converter tube
Noise and microphonics	*a, d* *c* *e*	Low emission or G_m Excess interelectrode capacitance Loose elements Corroded pins or contacts or grid cap Internal insulating material deteriorated or originally not properly constructed Leakage
Intermittent operation	*a*	Intermittent element shorts due to thermal expansion or jarring Intermittent short between heater and cathode Gassy

Valve Reference Books, Equivalent Tables and Web-Based Resources



Valves have had whole libraries of books written on them, ranging from early books on the theory of their operation and how to use them in simple circuits (eg. J. Scott-Taggart in the early-1920's, see Reference below), to comprehensive and mathematically-inclined tomes by F. Langford-Smith and others.

Also, as there were thousands of valve types produced by different manufacturers in different countries over several decades, there is also a vast number of valve characteristics data books and equivalent tables available (again, see References). These days, the internet has provided another useful source of data and information about valves – there is an extended list of some very useful websites provided at the end of this article that are well worth exploring. In addition to their web-site, the UK National Valve Museum (http://www.valve-museum.org) has a great DVD ROM available for a few quid that includes high-resolution photos as well as technical data on a wide range of valves: well worth checking out for those interested in this subject.



How Can I Test Valves?

By far the best way of testing a valve is by installing it in the circuit it will be operating in, however, sometimes it is useful (or necessary) to be able to check valve function and/or performance out of the circuit – usually because a known good replacement isn't to hand, or to match pairs of valves. If this is to be done, it is really necessary to utilize a valve tester of some description, although it is possible to test for heater continuity and 'dead shorts' between the valve elements using an ohmmeter, also, poor vacuum may be indicated by a white sheen inside the grass envelope (the getter), or an ionization glow when the valve is operating (be careful though, as some types, eg. cold-cathode voltage stabilizers, glow during normal operation).

When it comes to valve testers, there are testers and then there are testers… To the best of my knowledge these instruments have not been manufactured since the 1960's (though I have seen the occasional un-built kit for sale on EBay if you fancy making a 'new' one

and like soldering! – not cheap though). Testers range from the virtually useless to the extremely good but complex (and usually rarer and therefore sought-after and thus expensive). A brief description of the range of instruments available (on the second-hand market) is presented in the Tech Short on Test Equipment along with some web-based resources to find out more, eg. http://www.tone-lizard.com/Tube_Testers.html, so I do not intend to go into this subject in depth here.

After a bit of a false-start buying a Heathkit 'tester' (emission tester), I was fortunate in coming across a nice Precision Model 10-12 dynamic tester dating from the mid-1960's in a radio fleamarket for a very reasonable $50: although the Precision instrument is really only one or two rungs up the ladder from a basic emission tester, it is very well-made and so far has proven reliable in identifying valves that are under-par or totally unserviceable, also none of the valves it has indicated as being 'good' have failed to work in the circuits they have been intended for. Although it did not have a full list of valves on the internal 'roll-chart', it came with some update booklets and an instruction manual (often missing) and I was able to download more updates from the web. It has most of the usual valve sockets but was sadly lacking a B8A base, as fitted to some valves, eg. EAH42, used in some Eddystone sets in the late 1940's/early 1950's (eg. S.740, S.750). I made an adapter using a base donated for the price of a 'transatlantic pint' by Graeme Wormald (thanks Graeme!), a small plastic box, an octal plug and a bit of multicore wire – works a treat (see photo above). Strangely, the tester settings for these B8A-based valves were in the update booklets.

The 'Ultimate' Valve Tester? – the 'Master Tube Bridge' (Tomer)

How Can I Identify a Valve if The Markings are Worn Off?

Valve markings have a habit of wearing off (so be careful when wiping old, dusty valves with a cleaning cloth that may have alcohol or other cleaning agent on it – this often results in a shiny but unmarked valve!). If this happens and you do not know the valve type, try chilling the valve (fridge or freezer) and then breathing gently on it – the markings often re-appear momentarily - then write it on the envelope with an indelible marker. If this does not work, try a version of a trick Johnny taught me many years ago: he used to swipe the valve quickly through his sparse but well-'Brylcreemed' locks and lo-and-behold following a quick 'huhh' onto the valve the markings would (sometimes) re-appear. In this day and age of non-Brylcreemed locks, try placing a very light smear of Vaseline (or even Brylcreem[1], as you can still buy it, albeit perhaps with some embarrassment, http://www.brylcreemusa.com/), or other grease/emulsion onto a cloth, take a dampened watercolour brush and first run it over the

[1] For the younger reader, Brylcreem's purpose was/is to keep combed hair in place while giving it a deep shine or gloss: it gave us the need for anti-mockasas, helped greaser's get their name and keeps 'DA' and 'comb-over' hairstyles in place in all but hurricane-strength winds. It is essentially an emulsion of water and mineral oil stabilized with beeswax. Other ingredients are fragrance, calcium hydroxide, BHT, dimethyl oxazolidine, magnesium sulfate, and stearic acid. Apparently even David Beckham used it until he shaved his head…

greasy cloth and then across the glass of the valve – then try breathing on the valve gently at this point to coax the markings to appear.

If the above techniques fail, do a bit of sleuthing - check out the electrode wiring and form: some types have distinctive internal structure, eg, duo-triodes such as the 12AX7 type, or duo-diode, such as the 6AL5, even the distinctive diode anode support structures in duo-diode-triode types, eg. 6AT6, can be identified and provide clues. Rectifiers also have a very distinctive electrode structure and are often large enough that the element connections can easily be identified to discern the valve pin-out and whether the cathode is indirectly heated or not. When combined with the pin-out and base type (do a careful inspection of the internal connections and pin numbers), as well as the envelope type and location in the circuit (if known), then at least the generic valve type can usually be narrowed down significantly and sometimes the specific type identified. Use one of the illustrated museum sites listed at the end of this article to assist in visual identification.

Where Can I Buy Valves Nowadays?

Many entering the world of valve radio restoration (Eddystone or not) start out by being concerned that as it is over 50 years since the widespread use of valves, then new ones, or even used ones that still work ok, must be extremely rare, more so for valves dating from the 1920's and 30's. Fortunately, the most popular types were made in their millions and there are vast quantities of good used, NOS and even NIB valves around from as far back as the 1920's, readily available at reasonable prices: I personally was taken aback when in sourcing valves for my first restoration project a couple of years ago (a USA-made 5 valve TRF 'Neutrodyne' technology set manufactured by Kings-Hinners of Buffalo, dating from 1924), I had the choice of used, NOS, NIB '201A's from three different manufacturers, different envelope styles and even base 'finish'… tested used ones were only $12 each. Many NOS popular types can be bought for $5 to $10 each. Also, many types are still in production, eg. in Russia or China, particularly those used in audio amplifier and amateur transmitter applications, ie. rectifiers (eg. 5AR4), small-signal AF triodes (eg. 12AX7) and pentodes (eg. EF86), audio output (eg. EL34, KT66), together with some RF small-signal and RF power valves (eg. 6BA6 and 6146 types).

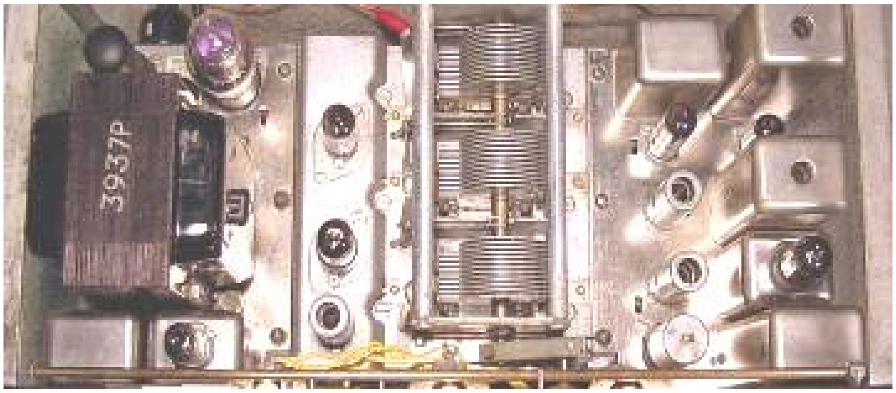
So, where can you buy valves nowadays – it is not quite as simple as popping down to your local radio repair shop – if one still exists, or 'drugstore' in the US/Canada, but it is not as difficult as you may fear:

- EBay: there are many 'EBay stores' specializing in supplying valves, as well as individuals disposing of valves from estate sales, old radio shops, family clear-outs and from private collections;

- Specialist valve suppliers focussed at the radio amateur: eg; Wilson valves (http://www.flashbacksales.co.uk/wilsonvalves/wvindex.htm) etc, specialist valve suppliers focussed on the 'antique' radio market, eg: Antique Electronic Supply (http://www.tubesandmore.com/) ; and

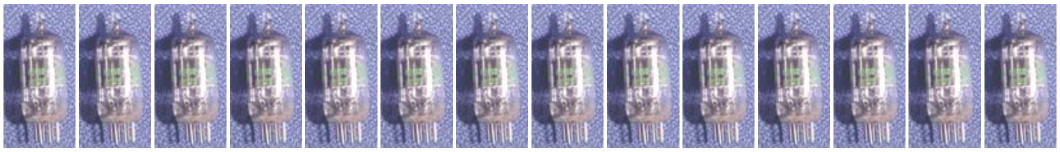
- Music stores (yes, music stores): my local ones stock a range of rectifier and audio valves at competitive prices (as used in guitar and 'vintage' organ amps). I recently bought a Sovtek (Russian-made) 5AR4 rectifier (GZ34 equivalent) for my S.940 there for $16.

Do I Need To Keep a Stock Of Spare Valves?



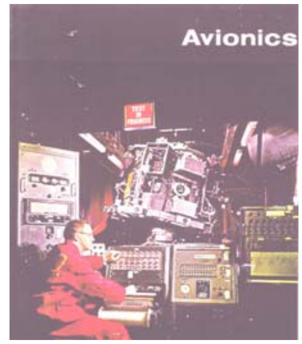
Not really, though one of each type used in your collection of working receivers would probably be useful to minimize 'down-

time' in case of a failure and can also serve as a substitute check against a suspect failing valve, especially if a valve tester is not available. Notwithstanding, a replacement valve can usually be sourced and delivered within less than a week.



Should I Change Valves, or Even Complete Sets of Valves, at Intervals Just As A Precaution?

If a receiver is being used in a 'mission critical' application, then maybe there is an argument for doing this: many military and commercial service procedures included such valve change-outs. As EUG'ers likely do not use their cherished sets in such applications, I would therefore not recommend doing this unless cost isn't a consideration: instead, develop one or two benchmarks of receiver performance, eg. a known signal strength from a signal genny through an attenuator, noise level on the various bands covered (testing the receiver against these every now and again), or when in use there appears to be a drop-off in receiver performance. Alternatively (or as well), try substituting a new valve, if available, in place of a suspect one as noted above: if there is little or no discernable change in performance, then place the original back in the receiver and the new one back in its box (some caution should be exercised in RF stages however, especially at the higher HF, VHF and UHF frequencies, as the new valve may de-tune the tuned circuits).

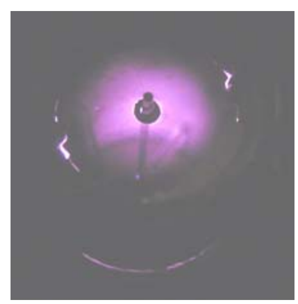


Possibly a case for changing 'em all out now and again

Conclusion

There is plenty of life in the 'old dog' yet: a renewed interest in thermionic technology in relation to high-quality 'audiophile' audio amplifiers, guitar amplifiers and pre-amplifiers, as well as in 'antique radio' restoration (by both radio amateurs and those interested in domestic 'broadcast' and shortwave radios), along with modern ways of searching for and buying valves, have all contributed to this. Unfortunately, this increased popularity has led to some rarer valves and valve-related paraphernalia becoming expensive – eg. valve testers were being thrown out in the 1970's and 80's and are now fetching premium prices on EBay and the like. Still, buying most popular/common valves, at least the limited range used in post-WWII Eddystones, is still relatively easy and affordable wherever you are in the world, whether from local suppliers or via the web.

There is nothing better than the warm glow of a valve heater to warm the heart and stimulate thought: my S.750 with its Perspex case has pride of place on my desk in my home-office and never fails to cheer me up on a cold winter morning when listening to stations worldwide, with the dull red glow of the tips if the 'NOS' 5Z4G rectifier cathodes and the mauve fluorescence of the 'NIB' VR150 doing stalwart service some 56 years after the set was constructed.



Gerry O'Hara, G8GUH, Vancouver, BC, Canada, December, 2006

Some Useful References and Notes on Same

- Wireless Valves Simply Explained, John Scott-Taggart, 1st Ed. 1922 (one of the oldest books in my collection, well written and in very good condition too)
- Radio Servicing Equipment, E. Lewis, 1950 (a UK book that includes good information on valve testers)

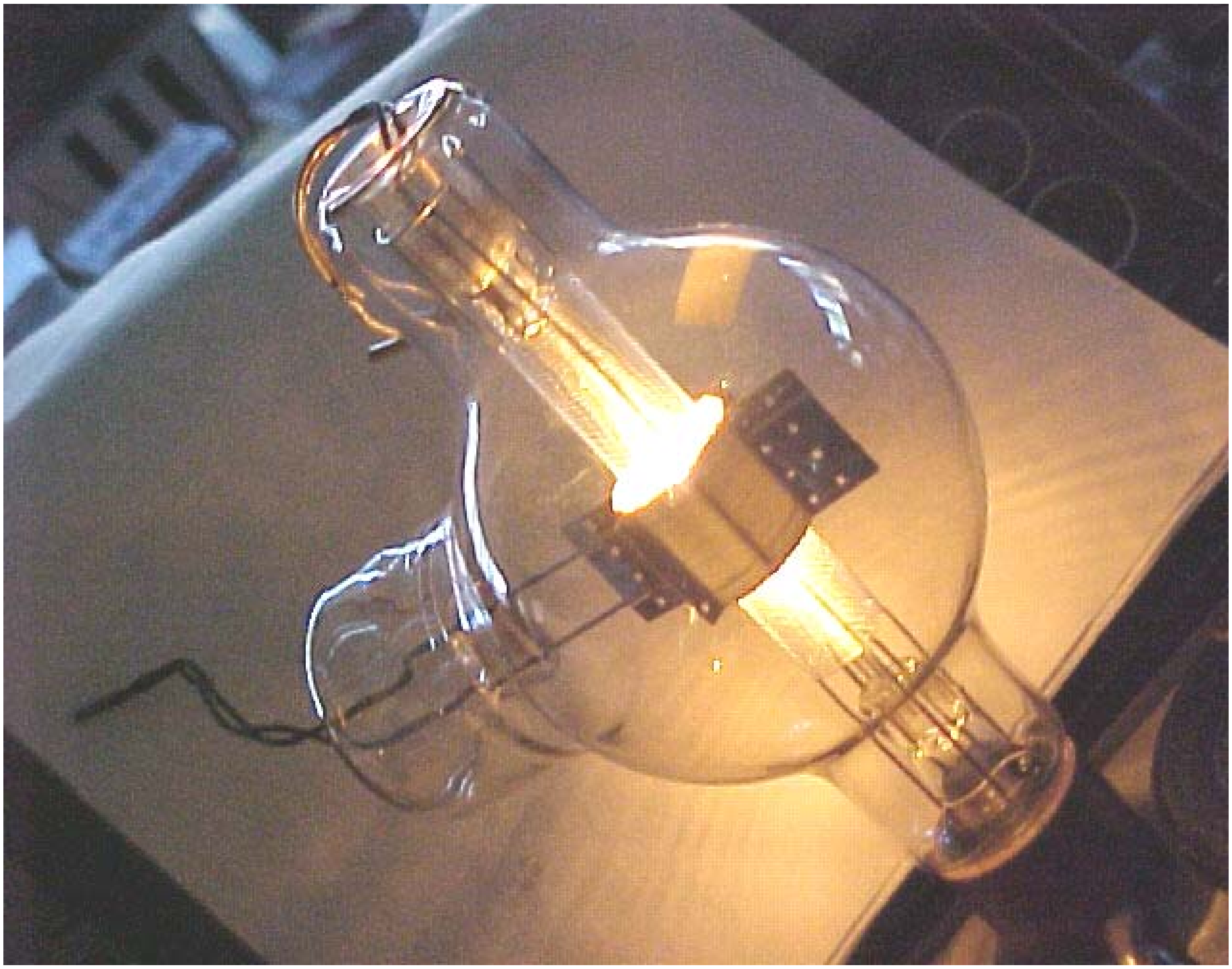
- Getting the Most Out Of Vacuum Tubes, R. Tomer, 1960 (I have an author-signed copy I picked up at a local fleamarket, but a reprint is available from Antique Radio Supplies, http://www.tubesandmore.com)
- The (UK) National Valve Museum (DVD ROM), 2006 (also see their website)
- Radio Receiver Service and Maintenance, E. Lewis, 1941 (1st Ed., Ch. 2)
- Radio Communications Handbook, RSGB (eg. 4th Ed, Ch. 2)
- Radio Amateurs Handbook, ARRL (eg. 31st Ed. Chapter 3)
- Elements of Radio Servicing, W Markus and A Levy, 1955 – I find the Markus and Levy books on radio servicing very understandable and practical, as are those by Ghirardi and Johnson – see references below: well worth keeping an eye out for on EBay or the many second-hand bookstores on the web)
- Modern Radio Servicing, A. Ghirardi, 1st Ed. 1935 (quite a remarkable tome for its day and it gives a great 'snapshot' on the radio 'state-of-the-art' in the early 1930's, albeit in the USA)
- Radio Engineering, F. Terman, 1947, (3rd Ed.) – a classic text, if a bit academic and 'stuffy'
- Radio Servicing: Theory and Practice, A. Markus, 1948 (esp. Ch. 3, which provides a very comprehensive expose of valve designations)
- Radio and Television Receiver Troubleshooting and Repair, Ghirardi & Johnson, 1952, (Esp. Ch. 1)
- Radio and Television Receiver Circuitry and Operation, Ghirardi & Johnson, 1951
- RCA Receiving Tube Manual (mine is a 1950 copy found in a fleamarket for $3, but a reprint of both the 1959 and 1973 editions can be bought from Antique Radio Supply (http://www.tubesandmore.com), as can be many other interesting valve-related and 'antique radio' books)

- Radiotron Designers Handbook, F. Langford-Smith, 4th Ed. 1953 (considered by many as the 'Bible' of valve circuitry design, these tend to fetch a premium price on EBay as they are much sought-after by hi-hi and guitar amplifier folks these days. I bought a searchable CD ROM version for 1 cent on EBay, plus $5 postage!). I also own a 3rd Ed. (1941) that is much thinner and somewhat less useful (though tends to be much cheaper). I understand that reprint of the 4th ed. is available from some sources
- Super Radiotron Valve Manual, 3rd Ed. 1962 (Aussie-produced equivalent book)
- A Comprehensive Radio Valve Guide, W. May (Bernards Radio Manuals, UK), 2nd Ed. 1953
- Handbook of Radio, TV and Industrial Tube and Valve Equivalents, B. Babani, 1971
- Mullard Data Book, 1973/4 (I used to own a stack of these but regrettably chucked the earlier ones out in a clear-out several years ago)
- Radio Valve and Semiconductor Data, A. Ball, 10th Ed., 1975
- Radio Tubes Characteristics, Sylvania, 1950 (was 'bundled' with my Precision Valve Tester, ex. 'Waitcus Supply Company', Bellingham, Washington State)

- Various sections of Eddystone manuals downloaded from the EUG web site and specific articles in Lighthouse pertaining to valves in Eddystone receivers including:

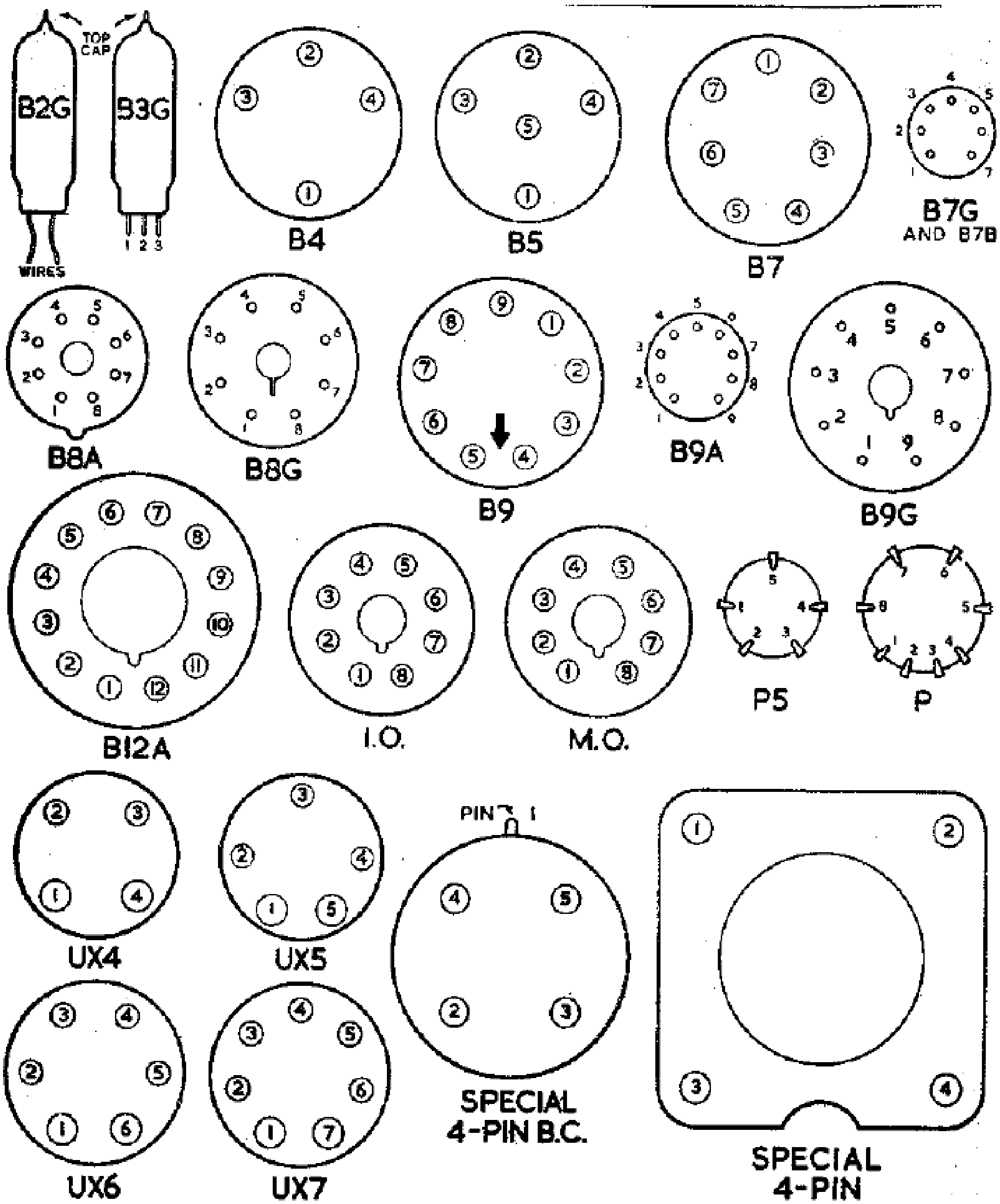
- Some web-based articles/resources on subjects covered in this article include:
  - http://www.valve-museum.org
  - http://www.tubesandmore.com/
  - http://users.iglide.net/hworth/radio/precision.html
  - http://www.xs4all.nl/~tgale/antradio/valves.html
  - http://www.tubecollector.org/
  - http://www.pamandandy.demon.co.uk/valves/

- http://www.vacuumtube.com/
- http://www.tubewizard.com/
- http://www.geocities.com/rxtxtubes/pa01000.htm
- http://www.audiotubes.com/speaking.htm
- http://www.radiotubesupply.com/
- http://store.tubedepot.com/
- http://www.vacuumtubes.net/
- https://www.tubeworld.com/index_high.htm
- http://thetubestore.com/index.html
- http://www.users.qwest.net/~tubes/
- http://members.aol.com/etetubes/
- http://www.cjseymour.plus.com/elec/valves/valves.htm
- http://www.tubedata.org/
- http://tubes_tubes_tubes.tripod.com/tubestubestubes/
- http://www.nostalgiaair.org/Tubes/
- http://www.radiomuseum.org/dsp_searchtubes.cfm
- http://www.tone-lizard.com/Tube_Testers.htm/
- http://www.flashbacksales.co.uk/wilsonvalves/wvindex.htm



A la Frankenstein?... a Type 860 in action

The long and the short of it… a 1930’s #42 alongside a 6AL5



Common valve base diagrams

My S.750 – a bastion of thermionic technology - plays amongst its high-tech friends on your-truly's desk.

Valves used in Eddystone Receivers Model 504 to 770RII by Tor Marthinsen EUG member

Eddystone Receiver:	504	556	640	659	670	670	680	680	700	710	730	740	750	770	770
Valves specified:						A+C		X						R	RII
5Z4G	1	1					1	1			1		1	1	1
6AF4 or 6AF4A															
6AJ8 or ECH81															
6AK5 or EF95														3	3
6AL5, EB91 orD77							2	2	1		2		1	2	2
6AM4 or 6AJ4															
6AM5, EL91 or 7D9							2	2			1			2	2
6AM6, 8D3 or Z77							1	1			2		1		1
6AQ5 or EL90															
6AT6, EBC90 or DH77									1				1		
6AU6 or EF94							2		2		1			3	3
6BA6 or EF93							5	5	5		5		3	5	5
6BE6 or EK90								1	1		1				
6BR7 or 8D5								2							
6C4 or EC90															
6ES8 or ECC189															
6K8GT			1	1											
6Q7GT			1												
6U8 or ECF82															
6V6GT	1	1	1	1											
6X5GT			1	1											
7S7 or X81							1								
12AT6															
12AT7															
12AU7											1			2	2
12AX7 or ECC83															
12BA6															
12BE6															
19AQ5															
25L6GT									1						
35W4															
5763															
5840 or EF732															
6489															
A2521															
DET22															
DM71						1									
E180F															
EAF42										3		4			
EB34	1	1	1	1											
EB41												1			
EBC33	1	1		1											
ECH35	1	1													
ECH42										1		1			
EF39	5	4	4	2											
EL42										2		1			
EM34		1		1											
EM80															
EZ40												1	2		
EZ41															
GZ34															
N78													1		
OA2 or 150C4															
OB2															
UAF41					4										
UAF42						3									
UCH41					1										
UCH42						1									
UL41					2	1									
UY41															
VR75/30									1				1	1	1
VR150/30 or OD3							1	1			1				
Valves, total	10	10	9	8	7	6	15	15	12	6	15	8	11	19	20
Eddystone Receiver:	504	556	640	659	670	670	680	680	700	710	730	740	750	770	770
						A+C		X						R	RII

Valves used in Eddystone Receivers by Tor Marthinsen EUG Member

770 S	770 U	770 UII	820	830	840 +A	840 C	850 /4	870 +A	880 /2	888	888 A	890 930	909 A+3	910	940	EA 12	
	1	1					1			1				1			5Z4G
1	1	1															6AF4
				1			1				2				1	2	6AJ8
1	1	1		1					2					2			6AK5
	2	2	1	1			1		1	1	1	1		1	1	1	6AL5
	1	1															6AM4
1	1	2					1		2						2		6AM5
11		1	3						1	2		7					6AM6
				1							1					1	6AQ5
				1			1			1	1			1			6AT6
2	3	3		2			1				1					1	6AU6
	2	2		2			3		4	3	2			2	3	2	6BA6
				1			1		1		1			2	1	1	6BE6
																	6BR7
				1					1		1		1	2	1	2	6C4
2				1					1						1	1	6ES8
																	6K8GT
																	6Q7GT
2				1					1			1					6U8
																	6V6GT
																	6X5GT
																	7S7
								1					1				12AT6
	2	2	1						2								12AT7
1	2	2							1						1		12AU7
																1	12AX7
								1					3				12BA6
								1					1				12BE6
								1					1				19AQ5
																	25L6GT
								1									35W4
														1			5763
									2								5840
									1								6489
2																	A2521
1																	DET22
						1											DM71
3																	E180F
																	EAF42
																	EB34
																	EB41
																	EBC33
																	ECH35
			1							2							ECH42
																	EF39
																	EL42
																	EM34
			1														EM80
																	EZ40
			1									1					EZ41
											1				1		GZ34
										1							N78
1				2										1		1	OA2
2									2								OB2
																	UAF41
					4	4											UAF42
																	UCH41
					1	1											UCH42
					1	1											UL41
					1	1											UY41
																	VR75/30
	1	1					1			1	1				1		VR150/30
30	17	19	8	15	7	8	11	5	22	12	12	10	7	13	13	13	
770 S	770 U	770 UII	820	830	840 +A	840 C	850 /4	870 +A	880 /2	888	888 A	890 930	909 A+3	910	940	EA 12	Tor M. 18.03.03

Page 1 Equivalent Valves used in Eddystone Receivers – See Page 2 for valves marked *

1N3 -> DM71	5750 -> 6BE6	CV 850 -> 6AK5	EAA91 -> 6AL5	NR48 -> EBC33
5AR4 -> GZ34	5751 -> 12AT7	CV1053 -> EF39	EAA901 -> 6AL5	OA2 -> *
5Z4G -> *	5763 -> *	CV1054 -> EB34	EAF42 -> *	OA3 -> VR75
5Z4GT -> 5Z4G	5840 -> *	CV1055 -> EBC33	EB34 -> *	OB2 -> *
6AF4 -> *	5861 -> DET22	CV1347 -> ECH35	EB41 -> *	OD3 -> VR150
6AF4A -> 6AF4	6005 -> 6AQ5	CV1352 -> EM80	EB91 -> 6AL5	OM3 -> EB34
6AJ4 -> 6AM4	6046 -> 25L6GT	CV1377 -> GZ34	EBC33 -> *	OM4 -> EBC33
6AJ8 -> *	6057 -> 12AX7	CV1581 -> ECH35	EBC90 -> 6AT6	OM6 -> EF39
6AK5 -> *	6058 -> 6AL5	CV1832 -> OA2	EC55 -> DET22	PM04 -> 6BA6
6AL5 -> *	6060 -> 12AT7	CV1833 -> OB2	EC90 -> 6C4	PM05 -> 6AK5
6AM4 -> *	6062 -> 5763	CV1855 -> EZ40	ECC81 -> 12AT7	PM07 -> 6AM6
6AM5 -> *	6064 -> 6AM6	CV1862 -> 6AQ5	ECC82 -> 12AU7	QA2401 -> 6C4
6AM6 -> *	6067 -> 12AU7	CV1863 -> 5Z4G	ECC83 -> 12AX7	QA2402 -> 6AM5
6AQ5 -> *	6073 -> OA2	CV1928 -> 12BA6	ECC189 -> 6ES8	QA2403 -> 6AM6
6AT6 -> *	6074 -> OB2	CV1930 -> EB34	ECC801 -> 12AT7	QA2404 -> 6AL5
6AU6 -> *	6094 -> 6AQ5	CV1946 -> 6K8GT	ECC802 -> 12AU7	QA2406 -> 12AT7
6AU6A -> 6AU6	6095 -> 6AQ5	CV1977 -> UL41	ECC803 -> 12AX7	QE03/10 -> 5763
6BA6 -> *	6096 -> 6AK5	CV2128 -> 6AJ8	ECF82 -> 6U8	QS150-40 -> VR150
6BE6 -> *	6097 -> 6AL5	CV2129 -> 5763	ECH35 -> *	QS1207 -> OA2
6BJ5 -> N78	6100 -> 6C4	CV2135 -> 6BR7	ECH42 -> *	QS1208 -> OB2
6BR5 -> EM80	6135 -> 6C4	CV2524 -> 6AU6	ECH81 -> 6AJ8	QS1210 -> OA2
6BR7 -> *	6136 -> 6AU6	CV2748 -> 5Z4G	ECH113 -> ECH42	QS1211 -> OB2
6BT4 -> EZ40	6189 -> 12AU7	CV2842 -> 6C4	EF39 -> *	QS2404 -> 6AL5
6C4 -> *	6201 -> 12AT7	CV3508 -> 12AT7	EF91 -> 6AM6	QS2406 -> 12AT7
6C10 -> ECH42	6489 -> *	CV3798 -> VR75	EF93 -> 6BA6	QV03-12 -> 5763
6C12 -> 6AJ8	6626 -> OA2	CV3881 -> EB41	EF94 -> 6AU6	R243 -> DET22
6CD7 -> EM34	6627 -> OB2	CV3883 -> EAF42	EF95 -> 6AK5	S856 -> OA2
6CT7 -> EAF42	6663 -> 6AL5	CV3888 -> ECH42	EF732 -> 5840	S860 -> OB2
6CU7 -> ECH42	6681 -> 12AX7	CV3890 -> EL42	EF861 -> E180F	SP6 -> 6AM6
6D2 -> 6AL5	6688 -> E180F	CV3891 -> EZ40	EF905 -> 6AK5	SR55 -> OB2
6ES8 -> *	7025 -> 12AX7	CV3929 -> 5840	EK90 -> 6BE6	SR56 -> OA2
6F12 -> 6AM6	A2521 -> *	CV3998 -> E180F	EL42 -> *	StR108/30 -> OB2
6K8GT -> *	AG5210 -> OB2	CV4003 -> 12AU7	EL90 -> 6AQ5	StR150/30 -> OA2
6L13 -> 12AX7	AG5211 -> OA2	CV4004 -> 12AX7	EL91 -> 6AM5	STV108/30 -> OB2
6M2 -> EM34	AR21 -> EBC33	CV4007 -> 6AL5	EM34 -> *	STV150/30 -> OA2
6P17 -> 6AM5	ARDD5 -> EB34	CV4009 -> 6BA6	EM80 -> *	TD03-10 -> DET22
6Q7GT -> *	ARP34 -> EF39	CV4010 -> 6AK5	EZ35 -> 6X5G	TS51 -> 6AK5
6U8 -> *	ARTH2 -> ECH35	CV4014 -> 6AM6	EZ40 -> *	U142 -> UY41
6V6GT -> *	B152 -> 12AT7	CV4017 -> 12AT7	EZ41 -> *	U147 -> 6X5GT
6X5G -> 6X5GT	B309 -> 12AT7	CV4020 -> OA2	G108/1K -> OB2	U150 -> EZ40
6X5GT -> *	B329 -> 12AU7	CV4022 -> 6C4	G150/4K -> OA2	UAF41 -> *
7D9 -> 6AM5	B339 -> 12AX7	CV4023 -> 6AU6	GD150A/S -> VR150	UAF42 -> *
7S7 -> *	BF62 -> EL42	CV4024 -> 12AT7	GD150M -> OA2	UCH41 -> *
8D3 -> 6AM6	BF451 -> UL41	CV4025 -> 6AL5	GZ30 -> 5Z4G	UCH42 -> *
8D5 -> 6BR7	BPM04 -> 6AQ5	CV4028 -> OB2	GZ34 -> *	UCH43 -> UCH42
12AT6 -> *	BVA243 -> EF39	CV4039 -> 5763	HBC90 -> 12AT6	UL41 -> *
12AT7 -> *	BVA246 -> EF39	CV4058 -> 6C4	HD51 -> OA2	UU9 -> EZ40
12AU7 -> *	BVA247 -> EF39	CV4063 -> 6AM5	HD52 -> OB2	UY41 -> *
12AX7 -> *	BVA274 -> ECH35	CV4100 -> OA2	HF93 -> 12BA6	V61 -> EZ40
12BA6 -> *	BVA275 -> ECH35	CV4101 -> OB2	HK90 -> 12BE6	V741 -> 6C4
12BE6 -> *	BVA276 -> ECH35	CV5065 -> 6U8	HL90 -> 19AQ5	V886 -> 6AM5
12S7 -> UAF42	CF141 -> UCH41	CV5074 -> 6AF4	HM04 -> 6BE6	VR53 -> EF39
14K7 -> UCH42	CK5654 -> 6AK5	CV5189 -> 6AL5	HP6 -> 6AM6	VR54 -> EB34
19AQ5 -> *	CK5726 -> 6AL5	CV5212 -> 12AT7	HY90 -> 35W4	VR55 -> EBC33
25L6GT -> *	CV 133 -> 6C4	CV5216 -> 6AK5	L77 -> 6C4	VR75/30 -> *
25W6GT -> 25L6GT	CV 136 -> 6AM5	CV5331 -> 6ES8	M8079 -> 6AL5	VR150/30 -> *
31A3 -> UY41	CV 138 -> 6AM6	D2M9 -> 6AL5	M8080 -> 6C4	VT-107A -> 6V6GT
35W4 -> *	CV 140 -> 6AL5	D63 -> EB34	M8082 -> 6AM5	VT180 -> EF39
45A5 -> UL41	CV 216 -> VR150	D77 -> 6AL5	M8083 -> 6AM6	W147 -> EF39
52KU -> 5Z4G	CV 273 -> DET22	D121 -> UAF41	M8096 -> 5763	W727 -> 6BA6
62TH -> ECH42	CV 283 -> 6AL5	D152 -> 6AL5	M8100 -> 6AK5	WD142 -> UAF42
64ME -> EM34	CV 394 -> EM34	DD6 -> 6AL5	M8136 -> 12AU7	WD150 -> EAF42
65ME -> EM80	CV 452 -> 6AT6	DDR7 -> 6AM5	M8137 -> 12AX7	X61M -> ECH35
66KU -> EZ40	CV 453 -> 6BE6	DET22 -> *	M8162 -> 12AT7	X77 -> 6BE6
108C1 -> OB2	CV 454 -> 6BA6	DH63(Met) -> EBC33	M8212 -> 6AL5	X81 -> 7S7
141TH -> UCH42	CV 455 -> 12AT7	DH77 -> 6AT6	M8223 -> OA2	X142 -> UCH42
150C2 -> 0A2	CV 469 -> 6489	DH147 -> EBC33	M8224 -> OB2	X147 -> ECH35
150C3 -> VR150	CV 491 -> 12AU7	DM71 -> *	ME1001 -> DET22	X150 -> ECH42
150C4 -> OA2	CV 492 -> 12AX7	DP61 -> 6AK5	N77 -> 6AM5	X719 -> 6AJ8
311SU -> UY41	CV 511 -> 6V6GT	E180F -> *	N78 -> *	X727 -> 6BE6
451PT -> UL41	CV 553 -> 25L6GT	E2157 -> 12AT7	N142 -> UL41	Y25 -> DM71
5654 -> 6AK5	CV 572 -> 6X5GT	E2163 -> 12AU7	N144 -> 6AM5	Z77 -> 6AM6
5726 -> 6AL5	CV 574 -> 6X5GT	E2164 -> 12AX7	N151 -> EL42	
5749 -> 6BA6	CV 589 -> 6Q7GT	EA76 -> 6489	N727 -> 6AQ5	Tor M 2003

Page 2 - Suggested alternatives for valves used in EDDYSTONE receivers: valves marked * on Page 1

5Z4G	->	CV1863	5Z4GT	52KU	CV2748	GZ30				
6AF4	->	CV5074	6AF4A							
6AJ8	->	CV2128	ECH81	6C12	X719					
6AK5	->	CV 850	EF95	EF905	5654	6096	DP61	M8100	PM05	TS51
″	->	CV4010	CV5216	CK5654						
6AL5	->	CV 140	EB91	D77	6D2	5726	6058	6097	6663	D2M9
″	->	CV 283	EAA91	EAA901	CK5726	D152	DD6	M8079	M8212	QA2404
″	->	CV4007	CV4025	CV5189	QS2404					
6AM4	->		6AJ4							
6AM5	->	CV 136	EL91	7D9	6P17	DDR7	M8082	N77	N144	QA2402
″	->	CV4063	V886							
6AM6	->	CV138	EF91	8D3	Z77	6F12	6064	HP6	M8083	PM07
″	->	CV4014	QA2403	SP6						
6AQ5	->	CV1862	EL90	6005	6094	6095	BPM04	N727		
6AT6	->	CV 452	EBC90	DH77						
6AU6	->	CV2524	EF94	6AU6A	6136	CV4023				
6BA6	->	CV 454	EF93	5749	CV4009	PM04	W727			
6BE6	->	CV 453	EK90	5750	HM04	X77	X727			
6BR7	->	CV2135	8D5							
6C4	->	CV 133	EC90	CV4058	6100	6135	L77	M8080	QA2401	V741
″	->	CV2842	CV4022							
6ES8	->	CV5331	ECC189							
6K8GT	->	CV1946								
6Q7GT	->	CV 589								
6U8	->	CV5065	ECF82							
6V6GT	->	CV511	VT-107A							
6X5GT	->	CV 574	6X5G	CV 572	EZ35	U147				
7S7	->		X81							
12AT6	->		HBC90							
12AT7	->	CV 455	ECC81	5751	6060	6201	B152	B309	E2157	M8162
″	->	CV3508	ECC801	CV4017	CV4024	CV5212	QA2406	QS2406		
12AU7	->	CV 491	ECC82	ECC802	6067	6189	B329	CV4003	E2163	M8136
12AX7	->	CV 492	ECC83	6L13	6057	6681	7025	B339	E2164	M8137
″	->	CV4004	ECC803							
12BA6	->	CV1928	HF93							
12BE6	->		HK90							
19AQ5			HL90							
25L6GT	->	CV 553	6046	25W6GT						
35W4	->		HY90							
5763	->	CV2129	CV4039	6062	M8096	QE03/10	QV03/12			
5840	->	CV3929	EF732							
6489	->	CV 469	EA76							
A2521	->									
DET22	->	CV 273	EC55	5861	ME1001	R243	TD03-10	TD03-10G		
DM71	->		1N3	Y25						
E180F	->	CV3998	6688	EF861						
EAF42	->	CV3883	6CT7	WD150						
EB34	->	CV1054	ARDD5	CV1930	D63	OM3	VR54			
EB41	->	CV3881								
EBC33	->	CV1055	AR21	DH63(M)	DH147	NR48	OM4	VR55		
ECH35	->	CV1347	ARTH2	BVA274	BVA275	BVA276	CV1581	X51M	X147	
ECH42	->	CV3888	ECH113	6C10	6CU7	62TH	X150			
EF39	->	CV1053	ARP34	BVA243	BVA246	BVA247	OM6	VR53	VT180	W147
EL42	->	CV3890	BF62	N151						
EM34	->	CV 394	6CD7	6M2	64ME					
EM80	->	CV1352	6BR5	65ME						
EZ40	->	CV3891	CV1855	6BT4	66KU	U150	UU9	V61		
EZ41	->									
GZ34	->	CV1377	5AR4							
N78	->		6BJ5							
OA2	->	CV1832	150C4	150C2	6073	6626	AG5211	G150/4K	GD150M	HD51
″	->	CV4020	CV4100	M8223	QS1207	QS1210	StR150/30	STV150/30	S856	SR56
OB2	->	CV1833	108C1	6074	6627	AG5210	G108/1K	HD52	M8224	S860
″	->	CV4028	CV4101	QS1208	QS1211	SR55	StR108/30	STV108/30		
UAF41	->		D121	(UAF42)						
UAF42	->		12S7	WD142						
UCH41	->		CF141	(UCH42)						
UCH42	->		14K7	141TH	UCH43	X142				
UL41	->	CV1977	45A5	451PT	BF451	N142				
UY41	->		31A3	311SU	U142					
VR75	->	CV3798	OA3							
VR150	->	CV 216	OD3	150C3	GD150A/S	QS150-40				

NOT included in the list are some ”Special Quality” types where the letters **W**, **WA** or **S** are added, or where the numbers are slightly interchanged. Here are a few examples: **OA2WA** for **OA2**, **6AL5W** for **6AL5**, **6AM6S** for **6AM6**, **AA91E** or **E91AA** for **EAA91**. They are all suitable for use in your Eddystone receiver.

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Since both Thermal Agitation Noise and Valve Noise are referred to the grid, the two voltages may be combined and the resultant will be the square root of the sum of the squares of the individual noise voltages. For example if the valve noise is 4μV. and the thermal agitation noise is 3μV., the resultant noise will be $\sqrt{4^2 + 3^2}$ or 5μV. This same method holds for any number of combined noise voltages.

When an R.F. stage is used ahead of the converter, the noise from the grid of the converter may be referred to the grid of the R.F. valve by dividing by the R.F. stage gain. Thus with a normal R.F. stage gain the converter noise becomes practically negligible either on the broadcast band or on short-waves, leaving the resultant of the thermal agitation noise and the valve noise of the R.F. stage as the total noise referred to the grid of the R.F. stage.

The noise at the grid of the first stage may be referred to the aerial terminal by dividing it by the gain of the aerial coil. The design of the aerial coil is therefore one of the principal features of the design of a receiver having high sensitivity.

The signal-to-noise ratio* for any given signal strength is the criterion of performance as regards noise, and is particularly important in a receiver having a sensitivity approaching 1μV. Increasing the gain of a converter valve decreases the noise referred to its grid, since the noise originates in the plate circuit. Consequently there is distinct advantage in obtaining maximum stage gain from the converter. No increase or decrease of gain following the converter has any effect on the signal-to-noise ratio. The selectivity of the I.F. amplifier, and the fidelity of the A.F. amplifier, affect the noise output as well as the higher audio frequencies in the signal. For communication purposes, where only limited fidelity is required, it is usual to cut the higher audio frequencies by using an extremely selective I.F. channel together with a manually operated A.F. tone control. The noise is reduced by this means in proportion as the audio frequency bandwidth is reduced, although the intelligibility is also reduced.

There are many articles on Noise to which reference may be made for further information. A short and simple survey is given by D. A. Bell, "Receiver Noise," Wireless World, March 16, 1939. For the relationship between noise and bandwidth see V. D. Landon, "A Study of the Characteristics of Noise," Proc. I.R.E., November, 1936. A good book on the subject is by E. B. Moullin, "Spontaneous Fluctuations of Voltage," (Oxford University Press).

The Application of Converters

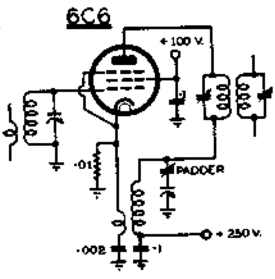

Figure 6.

Fig. 6 shows a typical *autodyne circuit* using valve type 6C6 although almost any other screen grid or pentode valve could be used in a similar manner. It can be seen from the circuit that the impedance of the tuned circuit is in series with the oscillator voltage as applied between grid and cathode. If the impedance of the tuned circuit at the oscillator frequency is appreciable (as will normally be the case with shortwave reception) then appreciable voltage of oscillator frequency will appear across the tuned circuit, thus tending to cause radiation, and the oscillator voltage appearing between grid and cathode will be reduced, thus causing inefficient operation. For these reasons the simple autodyne circuit as shown is not suitable for the higher frequencies, although there is a modified circuit which may be used.

*The signal to noise ratio under different conditions may only be compared when the input signal remains constant, or when the noise voltage is calculated in "ensi" (see Chapter 29).

Fig. 7 shows the circuit of the 6F7, a typical **triode pentode valve.** Similar remarks apply as for the autodyne. Fig. 8 shows a circuit incorporating the 6A8-G **pentagrid converter.** This circuit is equally suitable for operation at broadcast or higher frequencies. The values of components, as given on the circuit, are typical although some variation in the grid condenser and the oscillator grid leak is sometimes made. Neutralisation between oscillator grid and signal grid is frequently employed in order to improve the operation at the highest frequencies on the short-wave

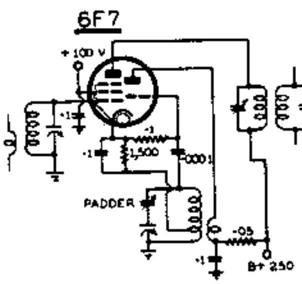

Figure 7.

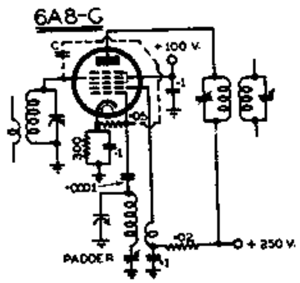

Figure 8.

band. This is obtained by a small condenser (see C in the diagram) which would normally be of the order of 1μμF. This needs to be adjusted under operating conditions for optimum results. Owing to the frequency drift caused by A.V.C. on the short-wave band, it is preferable for the 6A8-G to be operated at fixed bias on this band, but alternatively if A.V.C. is applied the I.F. amplifier may be arranged with a comparatively flat "top" so that reasonable drifts in frequency are permissible. The maximum voltage which should be applied to the anode grid of the 6A8-G is 200 volts; when operated from a higher voltage a dropping resistor is necessary. In order to avoid flutter the anode grid is frequently supplied directly from the filament of the rectifier valve through a dropping resistor with a suitably large by-pass condenser from the low voltage end of this resistor; good filtering is required to avoid modulation hum.

Fig. 9 shows a typical circuit of the **6L7-G mixer** with a 6C5-G (or 6J7-G triode) oscillator. Either direct or capacitive coupling is possible between the oscillator and the mixer with slight differences in operation between the two methods, and any of several oscillator arrangements may be adopted. The one shown may be regarded as only typical. On very high frequencies it is advisable to operate the 6L7-G with fixed bias in place of A.V.C. and to decrease the resistance of the grid circuit to the minimum. On the short-wave band it is also desirable to increase the minimum bias

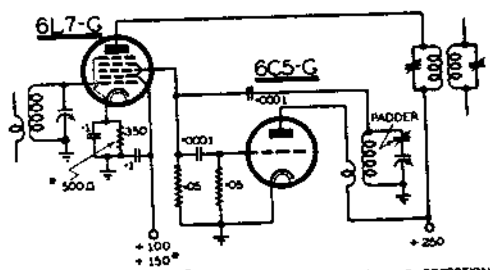

Figure 9

on No. 1 grid to —6 volts and then, in order to prevent loss of sensitivity, the screen voltage may be increased to 150 volts.

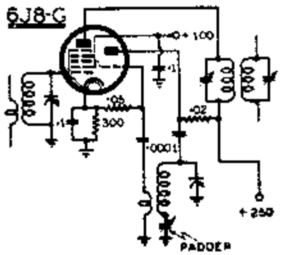

Figure 10.

Fig. 10 shows a typical operating circuit for the **6J8-G triode-heptode converter.** Direct coupling between the triode and the mixer is provided inside the valve but in other respects the operation is very similar to the 6L7G. No increase of screen voltage is permissible in the 6J8-G but this does not appear necessary in practice on the ordinary short-wave band. A.V.C. may be applied to this valve at all normal short-wave frequencies. Plate tuning is frequently used in the oscillator in order to improve the strength of oscillation and to provide better stability. Owing to the high plate resistance and low conversion conductance it is desirable to use a following I.F. transformer having high dynamic resistance. One method of assisting the attainment of a high dynamic resistance is to increase the L/C ratio by increasing the inductance and decreasing the capacitance to a limit of about 70 $\mu\mu$F.

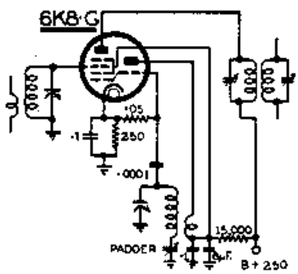

Figure 11.

Fig. 11 shows a typical operating circuit for the **6K8-G triode-hexode** and it will be seen that the circuit is essentially similar to that for 6A8-G. Owing to the fact that the voltage which may be applied to the oscillator plate is limited to 100 volts some modification of the 6A8-G circuit is necessary. In order to obtain the greatest stability in oscillator frequency it is desirable to use a common dropping resistor of 15,000 ohms from B + to both screen and oscillator plate. A by-pass condenser of about 8 μF. is sufficient to avoid all traces of flutter. Special high dynamic resistance I.F. transformers are not required for the 6K8-G although some benefit is given by an improvement in this direction.

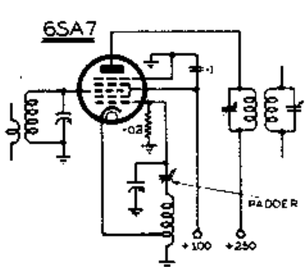

Figure 12.

Fig. 12 shows a typical circuit incorporating the **6SA7 converter.** A Hartley oscillator is employed in this circuit and only a single tapped coil is required. Various other alternative arrangements of the coil are possible. At the higher frequencies some improvement is possible by adopting a separate oscillator since otherwise it is difficult to obtain complete modulation. With self-excitation neutralisation similar to that with the 6A8-G is not satisfactory but with a separate oscillator it is beneficial. Owing to the high plate resistance, high dynamic resistance I.F. transformers are advantageous, but not necessary in most cases, since the conversion conductance is high.