RESTORING THE PHILCO MODEL 38-7 MW & SW RADIO FROM 1938.

Upgrading the radio with a Triode-Hexode Converter.

H. Holden. April. 2026.

INTRODUCTION:

The Philco model 38-7 radio represents one of the finest MW & SW band Domestic Radio Receiver to emerge from the USA prior to WW2.

These radios were shipped to many countries because as an option, they sported a dual voltage 110V/220V Line Power transformer. My radio, shown in the photo above, came to to NZ. I acquired it in the early 1970's and restored it initially around 1976. I had some help at the time from John W. Stokes, the author of the famous book 70 Years of Radio Tubes and Valves.

John had an excellent radio repair store on Dominion Rd in Auckland and he helped me with the Radio's alignment and some of the repairs. At the time he explained to me how the 6A8 Pentagrid Converter Tube worked. I soaked up the information like a sponge, being an enthusiastic 18 year old. John Stokes passed away in August 1999. I will never forget the way he helped me with Tube radio repairs.

At that point in my life I had very limited test equipment aside from an Analog Multi-meter and a Crystal Earphone, but I had access to a mechanical workshop and a Lathe.

This Philco model 38-7 radio recently required more work to keep it running. After all, the first restoration was just about 50 years ago now and the radio is about 88 years old.

The 38-7 radio has six Tubes and covers the MW band from 530kHz to 1720kHz and has a very wide range SW Band specified from 5.7MHz to 18.2MHz but it can actually tune from 5.5MHz to 19.5MHz as indicated on the dial.

INDUSTRIAL DESIGN & ARTWORK:

This is outstanding. For example the cabinet is a highly attractive Art Deco design, typical of the late 1930's. It has inlaid veneers but not over cluttered. The cabinet architecture is creative. However, from a user's perspective, the most interesting thing is the Dial and the Tuning arrangements.

The tuning knob rotates around the outer dial perimeter and has a central shaft, call that shaft-X. The larger of the two knobs mounted on shaft -X and having a return spring, can be pushed inwards, slipping over the outer surface of shaft-X. This engages the dial ridges on the Dial Glass's Brass retaining ring. It is done with a rubber ring, on the rear of that larger knob. Then rotating the larger knob behaves as a type of reduction gear, for fine tuning process.

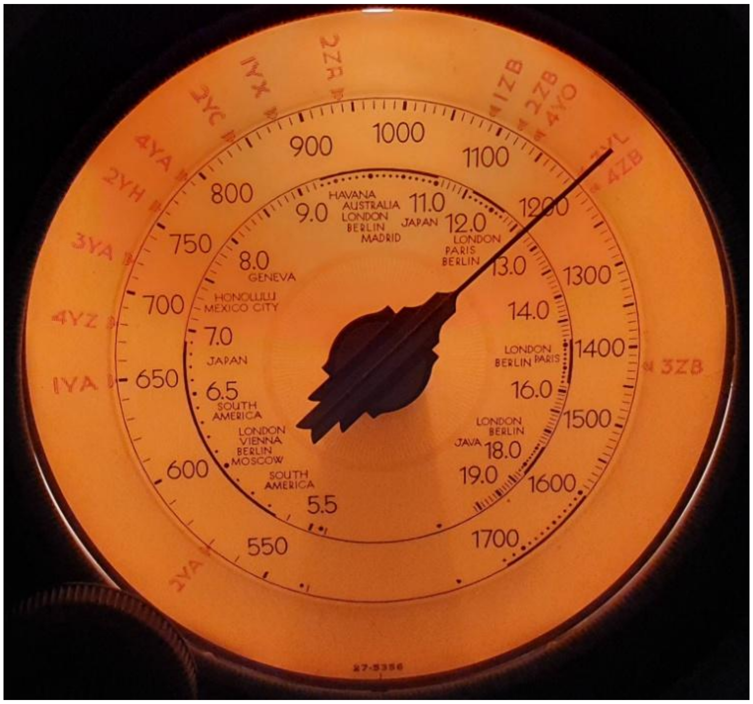
The extra machinery of that rotating arm and its physical mass is counter-balanced by a large mass on the central shaft, call that shaft-Y. This imparts the tuning mechanism with a very nice feeling in operation.

Behind the dial is a closed drum shaped chamber. It is painted white inside. Into that projects the dial lamp. This lamp diffusely illuminates the dial material, for a beautiful warm and welcoming orange glow.

Shaft-X and the smaller knob on it can move in and out and has additional functions. One is it can engage Metal Cones mounted on a rear vertical plate behind the dial drum. The Cones can be set to preset station positions to lock the variable capacitor position and hence the tuned station. This was called "Cone-Centric" tuning.

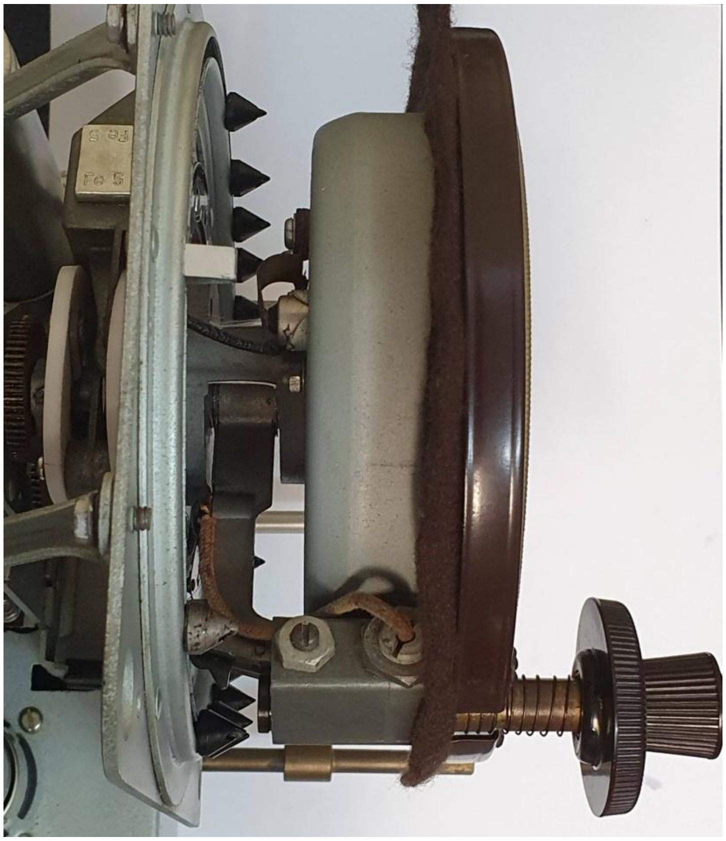
Also shaft -X contains an electrical contact which can mute the audio between the selected Cones and at different positions of shaft-X. If not using the cones, that feature is better disabled because if one is not expecting the audio muting, they can be caught out.

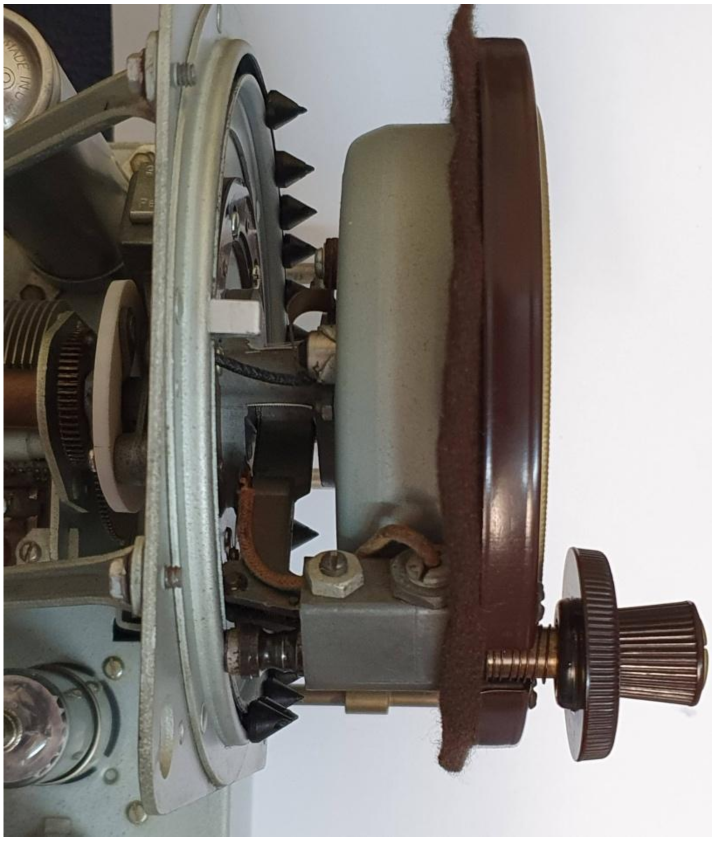
Shaft-X is attached to a Die-cast metal arm which attaches to and rotates the central Shaft-Y. Shaft-Y is on the dials dial's central axis and carries the dial pointer. Shaft-Y also passes though the vertical plate carrying the Cones and attaches via a flexible coupling to the input shaft and gears of the two gang variable tuning capacitor.



One of the most impressive features is the dial as shown above. The dial is good size at nearly 5 inches in diameter. It has highly accurate calibration detail and more resembles the type of thing seen on a scientific instrument than any domestic radio dial from 1938. Also up close, the dial plastic has an embossed surface with an elegant patterning effect. I shone a light at an angle in an attempt to show this in the photo above on the right. I'm certain that this remains one of the better radio dials from any radio of the late 1930's era.

The photo below left shows the dial drum area and the adjustable Cones on the vertical plate. In this case Shaft-X is not pushed in to engage a Cone yet.



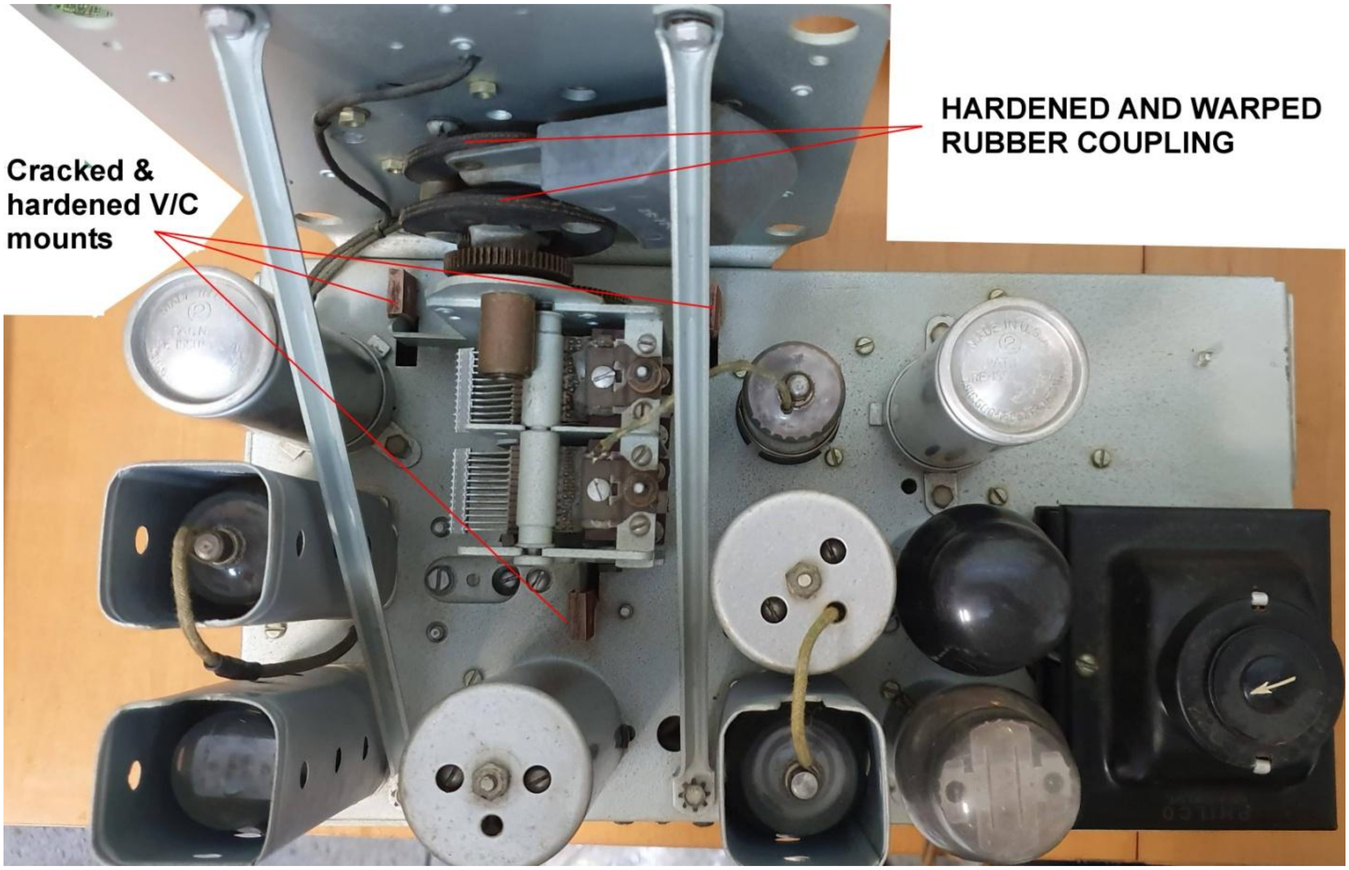


The wire passing into the assembly detects the position of the shaft-X for the Audio Muting. Also though, when Shaft-X engages a cone, a separate local mechanism in the rotating arm lifts a contact of a circular track, so the audio in that case is always unconditionally un-muted. Below right shows the Cone and Shaft-X engaged.

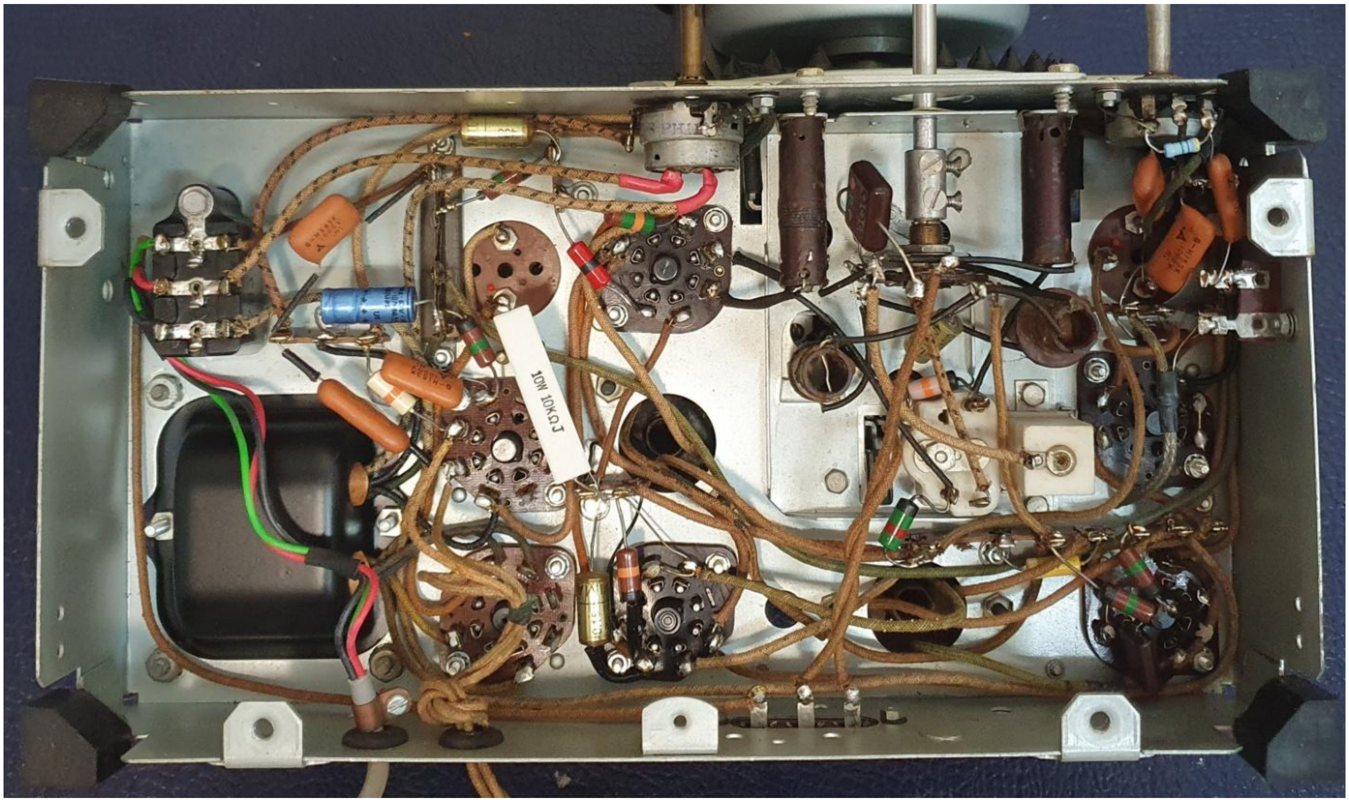
Other features of the tuning mechanism include a variable capacitor with a spring twin gear wheel arrangement to prevent backlash and a special universal rubber coupling. This coupling recently required re-building. The laminated rubber discs had become warped under the force of the counter-balance's mass and the rubber had become stuck in a stiffened deformed state. This resulted in a very irregular feel to the tuning mechanism.

Also since the first restoration the Variable Capacitor's rubber mounting feet had degraded. At the time, back in the 1970's, with no parts available I hand fashioned these replacements from some 5mm thick red rubber sheet using nothing more than a scalpel. But, over the last 50 years, this red rubber had hardened and cracked.

The photo below shows an overview of the chassis.



The chassis underside had held up very well over the years since the first restoration:



The original wax paper capacitors at the time were replaced with high reliability 1000V rated Mitsubishi light brown parts for long term reliability. I liked them because of the somewhat old fashioned look to them and the high voltage ratings would promote longevity.

Other wax-paper parts were replaced with axial Wima film capacitors and the Mica parts were still ok, even today. However many Mica parts do fail and become leaky at this age and some types suffer from a form of silver migration disease. It pays to check aged Mica parts carefully now.

The original Wet Electrolytic Capacitors were re-built with modern Electrolytic capacitors inside. This was done by machining a Phenolic base and adding solder terminals taken from some 4mm panel Banana plugs. The capacitor housings were then re-mounded using capacitor clamps, rather than the original screw and large nut arrangement that they once had.

All of the resistors were renewed. These (aside from the large wire-wound 10k part) were modern 1 watt rated parts. They were very carefully spray painted with the body-tip-spot colour code. I may have been the only person in the World back in the 1970's who was re-painting modern resistors to make them look age appropriate in appearance. I think this has become more of a fashion now with vintage radio & TV restorations. When John Stokes saw those repainted resistors back in the 70's he remarked that he could not see the point in doing that, but it made him smile nonetheless.

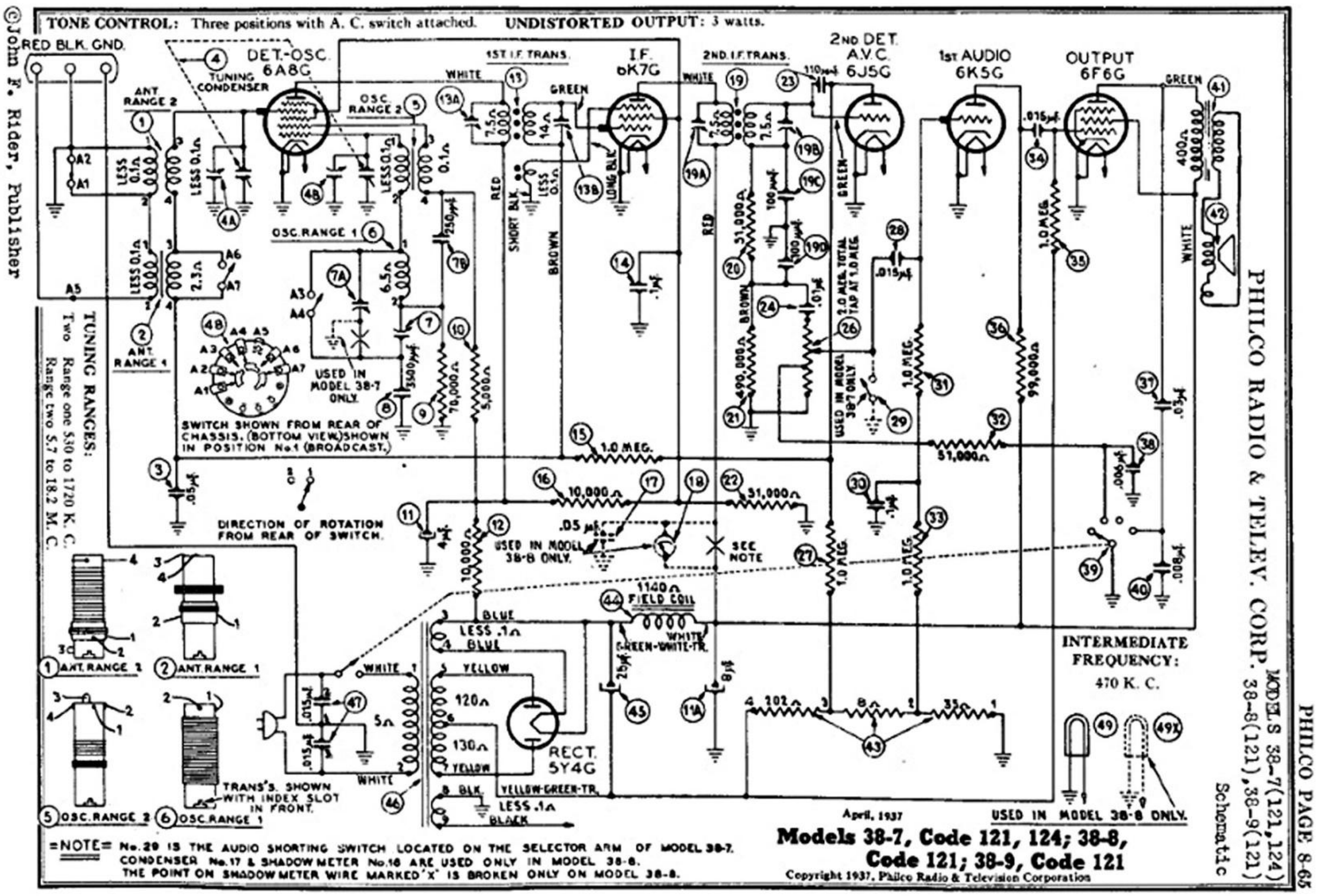
Of note, the Black Rectangular Box in the upper left hand corner (photo below) where the Phase, Neutral & Earth Line power terminations are made. It contains two 0.015uF capacitors. These should always be replaced with what we now know as Y capacitors. Generally in the 1930's "Y capacitors" with modern safety ratings did not exist. The designers simply used 1000v or 1500v rated parts to help avoid failure that way.

At the time of the original restoration the Tube socket rivets were removed and the IF transformers and upper chassis parts removed. The whole wiring assembly, largely complete, was removed from the chassis. All of the Tube sockets are retained by screws and nuts now. Fortunately Philco made good wafer sockets and none required replacing.

The chassis was re- electroplated in the 1970's. However over the last 50 years or so, some fine pitting and corrosion on the top chassis surface has started to reappear.

Electronic Design of the Model 38-7:

This is where things get very interesting. The design here is outstanding, with a number of innovations. The schematic below:



As can be seen, the converter tube is the Pentagrid Converter Tube, the 6A8. The IF Tube a 6K7, the detector and AGC system a 6J5. The 6k5 audio preamplifier tube feeds the classic 6F6 three Watt Class-A audio output stage. And the 5Y4 rectifier furnishes the B+ supply.

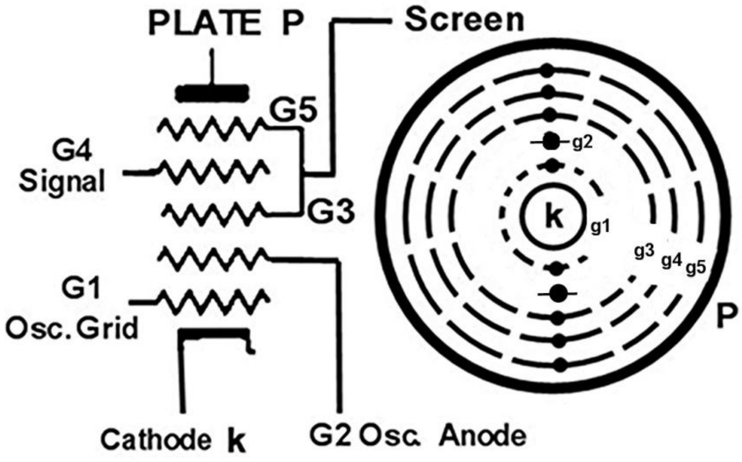
The Tube line-up, aside from the 6J5, was very common in 1938. The 6K7 was a fairly standard IF tube used in multiple radios with very similar electrical specifications to the 6U7. These Tubes are “Super-Control Pentodes” meaning that their gain can be well controlled, especially in an RF or IF stage, with the application of a negative AGC voltage. The 6J5 and 6K5 were also common general utility Triodes for Detector and Audio amplifier uses and other applications.

Pentagrid Converter:

The 6A8 Pentagrid Converter had its origins in April 1933 when RCA released the 2A7, which is the same thing, but with a different base and lower heater voltage.

The Pentagrid Converter Tube in the early 1930's era was a "revolution" as a method to combine a Superhet Radio's Local Oscillator and Mixer stage into the one Tube, while at the same time making the Mixer amenable to variable mu, for gain control by the AGC voltage. This meant that a very effective overall AGC could be created, with the same AGC voltage controlling both the Converter stage and the IF stage.

The 6A8 is a single cathode tube. All of the grid elements are placed concentrically around the cathode and the electron stream passes by all of them to the Anode (plate). The 1st grid, closest to the cathode acts as the grid for the Oscillator circuit and the 2nd grid acts as the Plate for the Oscillator. The g2 grid is a pair of rod like structures.



Pentagrid Converter Tube type 6A8

The trick to the design of the 6A8 is that the g3 grid acts as a Space Charge grid, or a virtual cathode, an effective electron source for g4. This 4th grid acts as the signal input grid, where the received radio station signal is injected from the Tuned Antenna circuit.

The g4 grid is the connection on the 6A8's top cap. The process which occurs within the 6A8 is ***multiplication*** of the Oscillator signal with the incoming RF signal. This idea of course predating the transistor and the now many modern IC's capable of voltage multiplication.

A multiplicative process is required to create the sum and difference frequencies, so as to create the IF channel frequency. In the 38-7 radio this is 470kHz. This is selected out of the signal components in the 6A8's Anode circuit by the first IF Transformer.

When two different frequencies f, of $\omega 1$ and $\omega 2$ are multiplied together ($\omega = 2\pi f$):

$$\mathrm{Cos}(\omega 1t).\mathrm{Cos}(\omega 2t) = 0.5\ \mathrm{Cos}((\omega 1 + \omega 2)t) + 0.5\mathrm{Cos}((\omega 1 - \omega 2)t)$$

The result is sum & difference frequencies ($\omega 1 + \omega 2$) and ($\omega 1 - \omega 2$).

Generally, in most radios, the local oscillator runs the IF frequency above the received frequency. For example if the received frequency coming into G4 of the 6A8 is 1000kHz, the oscillator will be running at 1470kHz. When these two signals get multiplied by the 6A8, the difference frequency is the 470kHz and this component is filtered off by the first IF Transformer and then passed off to the 6k7 IF tube for further amplification and filtering. Although the function of the 6A8 is, by design intention a "multiplier" there will be some curvature or non linearity which also aids its mixer function.

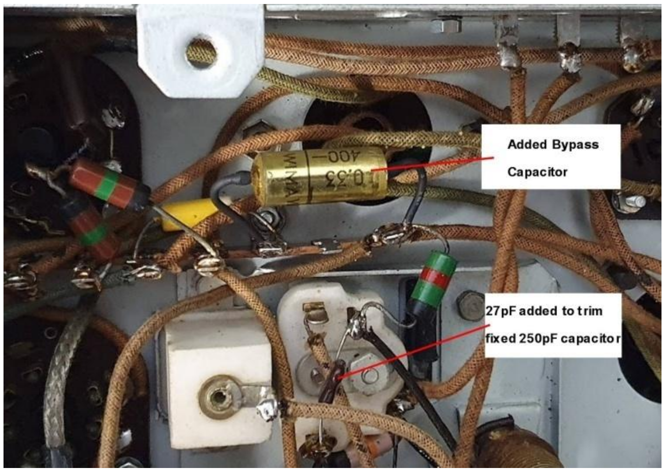
SW Oscillator Issues in the 38-7 Radio:

I found on testing that the sensitivity of the radio dropped fairly significantly on the SW band above 12MHz. Some of this is expected because of the performance of the 6A8 at the higher frequency end in known to be somewhat deficient.

Later converter tubes such as the 6k8 Triode-Hexode converter (released a little late for the 38-7 radio's designers) were designed to improve upon the high SW reception and AGC behavior of the Pentagrid Converter tubes such as the 6A8.

Investigation revealed a 3rd harmonic content in the Oscillator signal, when in the region of 16 MHz, the frequency of it at around 48 MHz. This harmonic was very high in level almost swamping out the fundamental wave. It took me a while to discover that this was due to a resonance of the primary of the SW Oscillator coil, connected to the g2 grid of the 6A8 and resonating with the capacitance there. This was not a problem with the 6A8 itself, more related to the proportions of the primary of the oscillator coil and the level of damping in the primary circuit.

Also the issue was affected by the fact that the 4uF bypass capacitor (11) on the B+ supply is an electrolytic type and poor at bypassing high frequency RF. Bypassing that electrolytic with a 0.33uF film capacitor suppressed most of the 48MHz oscillation, but then, interestingly a high level 5th harmonic appeared at around 80MHz.



(Unrelated to these issues a 27pF capacitor was also added to trim that value of the fixed 250pF capacitor in the ceramic block (7B) as it was a little low)

To damp the very high frequency resonances out I replaced the link wire between the oscillator coil primary and the 6A8 socket pin 6 (the g2 grid) with a 150 Ohm resistor. This damped the resonances and removed nearly all of the harmonics and gave a good clean oscillator fundamental over the whole tuning range on the SW band and had no practical effect on the MW band.

This move improved the high frequency end shortwave reception. Probably all of the 38-7 radios were affected by this. It wasn't until I had a 100MHz capable scope with a very low input capacitance x100 probe (the Tek P6009 - only 2.5pF) that I was able to detect and remedy this issue.

In general though it is fair to say that *some* higher order harmonics in the local oscillator of a typical radio are not a problem, especially because in the G1 grid circuit, the resonance of the tuned circuit there dominates over them and a clean sine wave is nearly always seen at that location, even if the Tickler winding shows some harmonics and some distortion.

The Mixer's Electron Stream Issue:

A quirk of the 6A8 is that the AGC control of its RF gain, affects the running frequency of the oscillator section of it. Ideally it would not, but it does. The effect of this is more noticeable on the high SW band with a strong enough signal to get the AGC to shift from its normal inactive state of -2V up to -6V or more. Increasing negative AGC voltage ***increases*** the oscillator's running frequency with the 6A8.

Since the Oscillator part of the 6A8 and the Mixer part of the tube, are both dependent on the same electron stream from the cathode, they interact.

With the 6A8, when a strong SW station is tuned in, with the oscillator initially running below the required value to tune in a station, an issue becomes evident on tuning the station:

For example let us say the station was on 16MHz, requiring an oscillator frequency of 16.470 MHz to tune into it, and the oscillator is sitting at around 16.300MHz and increasing as the user moves the tuning knob toward the station. Then as the signal is received and the AGC voltage is increasing, there is a rapid increase in oscillator frequency and an avalanche increase in the AGC voltage. The oscillator frequency jumps up, often over the 16.470MHz mark. Therefore the station appears to abruptly jump into tune and overshoot sometimes too, requiring some more fine tuning effort.

This undesirable effect is not too noticeable on the low SW band below 10MHz or the MW wave band at all as the tuning is less critical for any rotational angle of the variable capacitor.

On weak stations (which most SW band ones are in my locality) the effect is not witnessed. This effect seen with a Pentagrid Converter such as the 6A8, is more significant compared to a Triode-Hexode converter such as the 6K8. In addition a Triode-Hexode converter tends to have less noise than the Pentagrid type.

RCA's AN-87 document from 1938 is shown below:

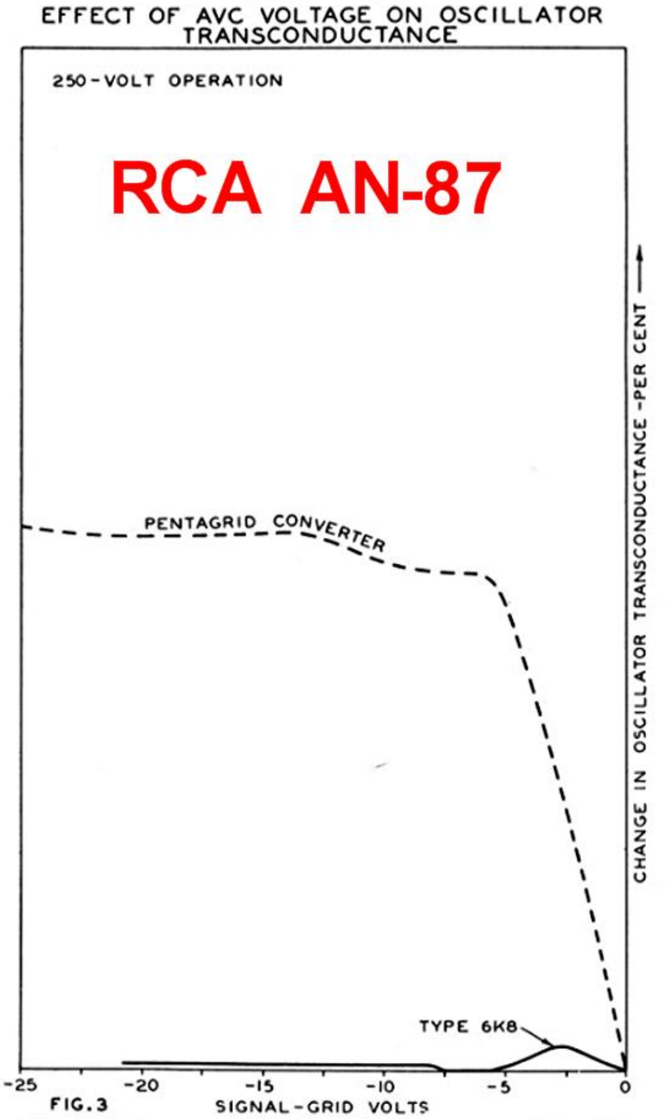


FIG.3

JAN. 21, 1938 RCA RADIOTRON DIVISION RCA MANUFACTURING COMPANY, INC. 92C-4873

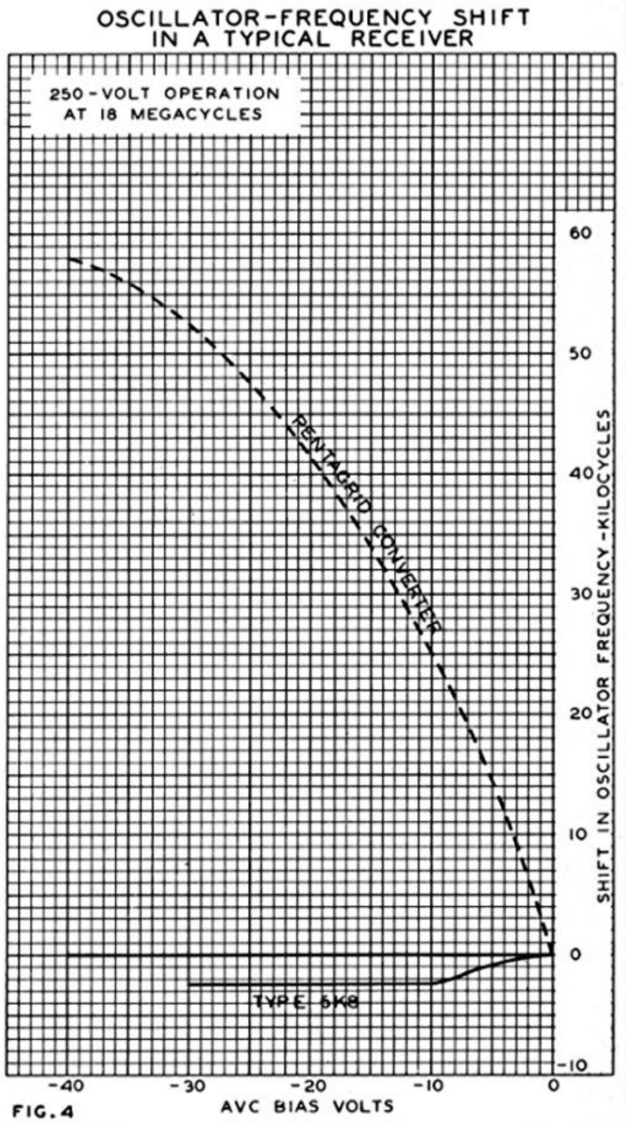


FIG.4

JAN. 21, 1938 RCA RADIOTRON DIVISION RCA MANUFACTURING COMPANY, INC. 92C-4874

On the other hand, the 6k8 tube experiences a *downshift* in frequency with increasing applied AGC(AVC)voltage as the graph on the upper right shows and the magnitude of the frequency shift is much lower than for the 6A8.

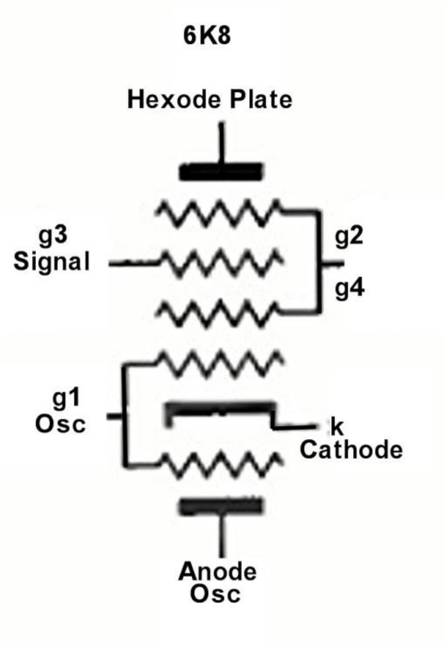
The 6A8's large AGC dependent frequency shift is because the AGC voltage has more of an effect on the Transconductance of the Oscillator section. This is the inevitable consequence of the Oscillator section and the Mixer part of the tube, sharing the same electron stream.

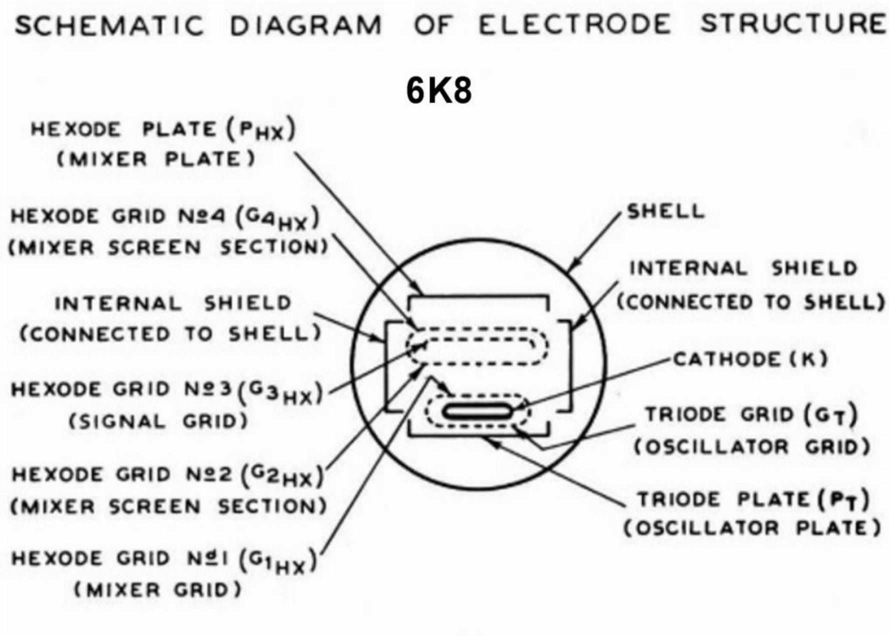
Interestingly, there has never been any other Mixer Tube in history constructed in the USA with the internal architecture of the 6k8.

The 6k8 stands on its own, in the field of Triode-Hexode converters in the USA (From John Stokes's book; 70 Years of Radio Tubes & Valves) Though some tubes of similar internal architecture were made later in Europe.

RCA chose to place the 6K8's Anode of the Hexode and the Anode of the Triode on opposite sides of the same cathode, so each plate at least receives electrons from opposite sides of the cathode.

The diagram below shows this. The basic idea was to separate the electron streams of the Triode and Hexode:





Another interesting feature of the 6k8, is that at high frequencies, its g3 signal grid input resistance is negative. This tends to act as a Q multiplier for the resonant circuit feeding it. This was discovered at RCA, where an improvement in selectivity and image rejection was noticed on testing it.

There are other mixer tubes with higher Conversion Transconductances than the 6k8, these include the Philips ECH35. This was introduced in 1939. It appears to be a further development of the British converter, the X41 released in 1936. These tubes have an internal architecture where the Triode part is better physically separated from the Hexode part to help further reduce interactions between the two sections.

The Triode's grid is connected internally to a grid in the Hexode to couple the oscillator's signal into the Hexode this way. Even though the cathode is shared the electron stream for the two parts of the tube is separate. The Triode assembly sits concentrically with the cathode, but below the Hexode, separated by a double mica support. The Triode's grid connection passes upwards into the Hexode. This short link is devoid of any significant reactive effects over the frequency range that these tubes operate at, making it a better arrangement in some respects, than having a triode tube in a separate socket and having to couple that into a separate Hexode acting as the mixer.

The X41 converter tube was used in the 1939 HMV-904 Television Set as the frequency changer, its oscillator running on the one fixed frequency at 37.0MHz. The manufacturers of the X41 claimed it would operate at 5 meters (60 MHz). In 1936 such a converter tube had not been created by RCA. The X41, a 4V 1.2A heater tube.

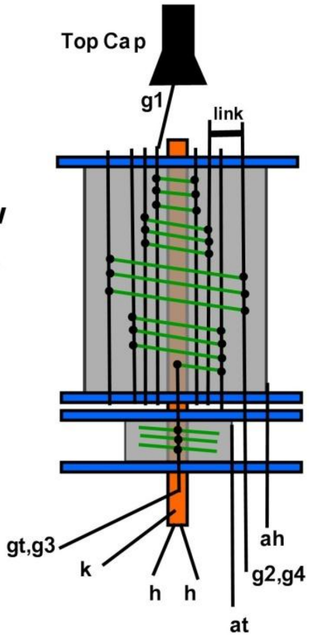
The internal architectural diagram of the X41/ECH35 design is nearly impossible to find, I had to draw it after examining a tube. Also notice that quite unlike the 6K8, the g1 grid of the Hexode is the Signal grid and the oscillator injection grid is g3, directly from the Triode's grid gt.

Below is a photo of the remarkable "ahead of its time" X41C, which is the ceramic base version of the X41. The ceramic base was used to remove the last possible traces of oscillator drift.

X41C

Circa 1936.

Partial Diagram to show grid arrangements X41/ X61/ ECH35 Triode-Hexode Converter.



Due to the superior performance of converter tubes such as the 6k8 and ECH35 and X41, compared to the Pentagrid tube such as the 6A8, I had given some consideration to fitting one of these tubes to the Philco radio instead.

I selected the ECH35, because it has a known higher conversion Transconductance than a 6K8 and it can plug directly into the octal socket in place of the 6A8, without rewiring the socket. However, because there was no pin 1 tag fitted in the actual socket (to earth the conductive coating on the ECH35) I linked pin 1 & pin 8 (the cathode) between the pins on the actual tube's base.

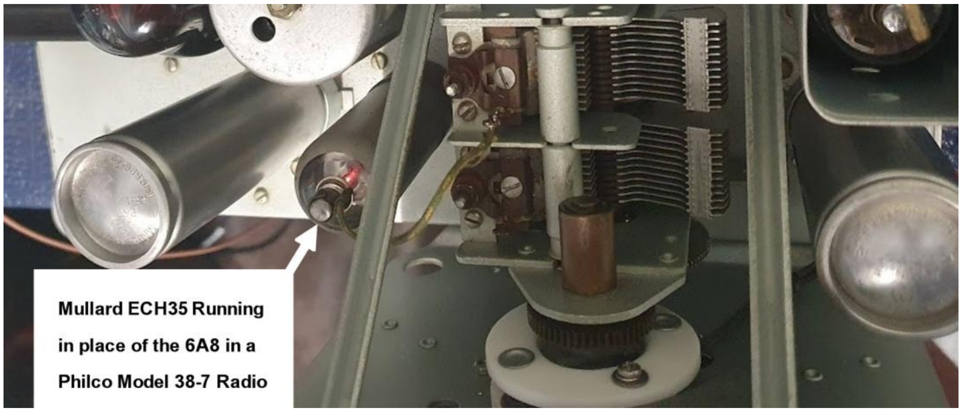
No significant changes were made except altering the wiring of one resistor part 10, this 5k resistor was simply moved from the junction of part 12 and part 16 on the schematic, to the junction of part 16 and part 22. This was to bring the Anode voltage of the Triode section of the ECH35 down to a voltage within its maximum specification. I re-aligned the radio, because the capacitances of the two converter tubes are a little different. The oscillator behaved perfectly normally on both bands with the ECH35. Also the 22 Ohm cathode resistor was shorted out as the tube is designed to run with a grounded cathode to minimize Triode-Hexode interactions.

On testing the radio I found improved sensitivity and less noise.

From the low MW band, up to the 14MHz mark, the sensitivity had improved from 10uV to 5uV. The 5uV figure almost starting to rival a set with an RF stage of 2uV, though obviously with less selectivity. And the AGC operation on stronger signals was improved with less frequency pulling.

Interestingly, the the noise heard with the ECH35 has a different sound to the 6A8, with more low frequency components. The 6A8 has a preponderance of higher frequency noise. This is likely due to the higher level of phase noise with the 6A8, compared to the ECH35 or 6k8.

From 14MHz to 19MHz area, the sensitivity toward 19MHz improved to around 12uV, still about twice as good as it was with the 6A8 at around 24uV in this part of the band. Therefore I elected to leave the ECH35 in the radio, as the performance improvement was too hard to ignore:



Mullard ECH35 Running in place of the 6A8 in a Philco Model 38-7 Radio

The Delayed AGC Circuit and the Active Clamp in the Philco 38-7:

The arrangement in the 38-7 with the 6J5, meant the radio had one more Tube in the “Tube count” than the typical 5 tube radio. Often 5 tube radios used a tube such as a 6Q7 which incorporated two diodes, along with the Audio amplifier Triode.

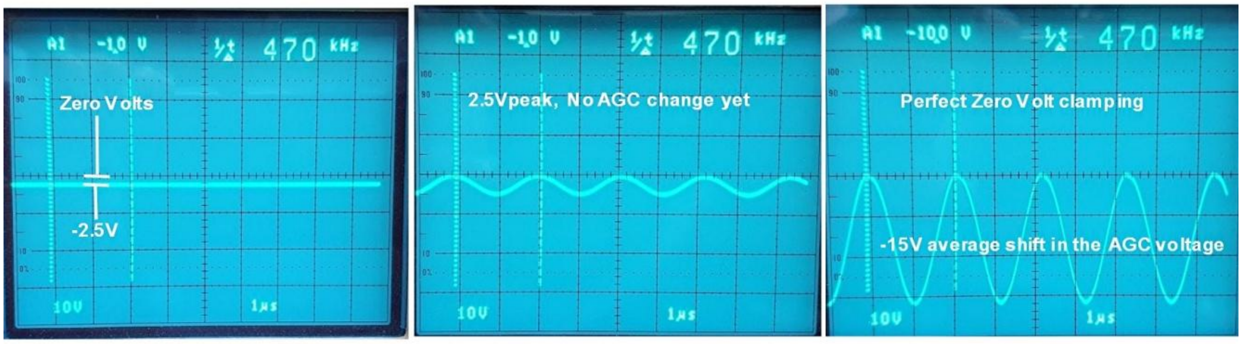
The tube count might have been a marketing feature, but the use of the 6J5 in this case is clever. Philco were justified in adding it to the Radio’s tube count from the marketing perspective if they did, because the tube performs a useful function.

To get the AGC to work to good effect, this circuit deployed the 6J5 Tube used in an unconventional manner. The Grid-Cathode was used as the AM detector diode, while the Anode was died to a negative potential derived from the “Candohm” resistor part 43 on the diagram.

The Candohm resistor is merely a three part wire wound resistor in the power supply’s negative terminal (the transformer’s center tap) to ground. A negative voltage is developed across it for Bias applications. This is to Bias the AGC line, bias the Anode of the 6J5 and bias the grid of the 6K5 and the g1 grid of the 6F6 audio output tube. This is called Fixed Bias, rather than having to rely on self cathode bias with cathode resistors or other bias methods.

It is not until the peak positive going IF voltage, coupled by the 110pF capacitor (part 23 on the diagram) to the Anode of the the 6J5 exceeds the applied negative voltage value of about -2.5V, that the 6J5 develops Anode current on the IF carrier peaks. This solidly clamps the carrier peaks on the Anode close to ground potential, shown below, scope on DC coupling:

Voltage On Anode of 6J5:



Zero Volts at Antenna

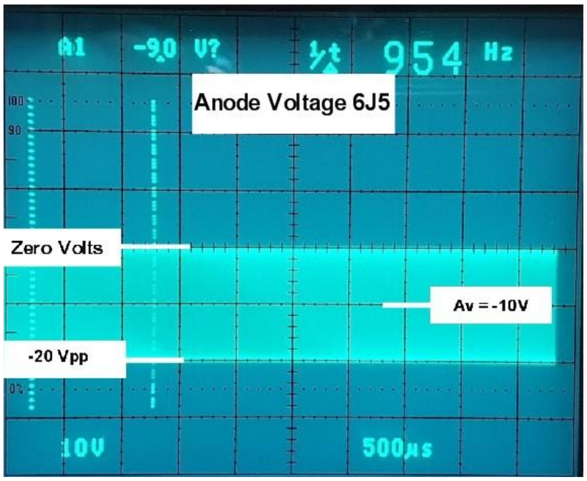
50uV rms at Antenna

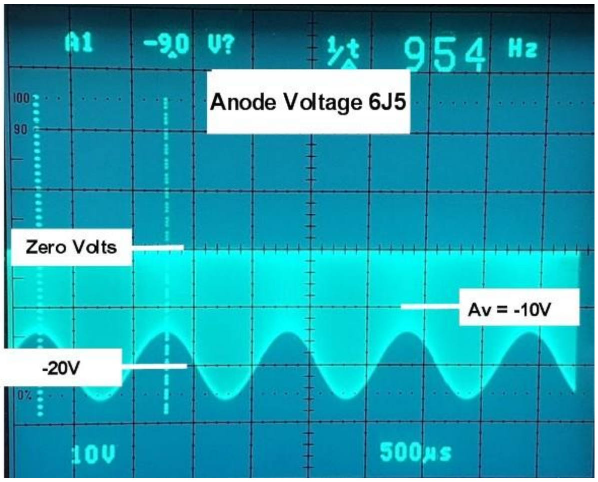
50mV RMS at Antenna

The initial negative bias on the Anode of the 6J5 delays the development of increasing negative AGC voltage until the carrier voltage at the antenna input exceeds about 50uV. Below that antenna RF input value the AGC is kept inactive.

As can be seen from the recording above right, the actively driven 6J5 makes for an excellent peak carrier clamp.

Any increase in the IF carrier amplitude results in an increasing average negative shift in the AGC voltage. The photo below left shows an example with the Anode voltage of the 6J5 with an initial un-modulated 470kHz IF voltage, coming out of the IF transformer of 20Vpp. When this signal is time averaged by the 1 Meg resistor (part 15) and the 0.05uF AGC filter capacitor (part 3) this provides about -10V of AGC voltage.





At the time of the 6J5's Anode conduction the carrier peaks are also driving the 6J5 into grid current, so when the Anode does conduct, the 6J5 acts in an analogous manner to what we now call an "active or driven clamp" and is a very efficient active rectifier.

The photo above on the right shows the situation with the modulation added. This does not affect the average AGC voltage derived. The reason for this is that RC time constant of the 110pF capacitor (23) and the 1 Meg resistor(27)is short enough that the capacitor can discharge fast enough to track the carrier's modulation envelope.

This Anode clamp circuit, while similar at high signal levels to the typical AM detector, cannot be used as the radio's detector, because of the initial negative voltage applied to the Anode, which causes it to stop its action if the carrier voltage out of the IF is below about 2.5V peak.

Stability Issues and Unique IF Neutralisation:

Philco found after the original production models that in some cases there could be instability in the 6A8 converter stage at the top end of the SW band. To ameliorate this they added a 22 Ohm resistor in series with the 6A8's Cathode connection & ground. This resistor is present in nearly all under chassis photos of the 38-7 I have seen, but it is not on their original schematic. It is handy to have it, because it is a useful place to monitor the tube's cathode current and also to detect the oscillator frequency without significantly pulling it. However after changing the converter tube to the ECH35, I shorted it out because it encourages interactions between the Triode & Hexode parts of the converter.

Philco tended to produce very high quality IF Transformers and the gain of their IF Stages was relatively high. Instability could occasionally be a problem there too. The fundamental problem of instability in an IF stage relates to the fact that the IF Tube's (or transistor's) input and its output both have high Q tuned circuits at exactly the the same operating frequency. Any electric, magnetic or capacitive interactions between the two resonant circuits results in energy transfer between them and instability and oscillations can occur.

All active amplifying devices have an output to input feedback capacitance and this is how the the energy can exchange between the two tuned circuits. Early transistors with high feedback capacitances in the order of 10pF always required Neutralization to cancel this effect. Later Transistors with feedback capacitances in the order of less than 1pF seldom needed it in a 455kHz IF stage. A screen Grid Pentode, such as the 6k7 would seldom require Neutralization because the screen grid provides near total (but not 100%) anode to g1 grid isolation. Still, occasionally, even the screen grid Pentode IF stage, can have a tendency to be unstable.

Close inspection of the 38-7's schematic shows that there is an additional coil, not often seen, inside the first IF transformer. This is merely a few turns of insulated wire wrapped around the secondary coil, feeding the grid of the 6k7. It took many years and having a good scope, such as the Tek 464, that I was finally able to examine the effect of this small coil and observe the relative coil polarities, not shown on the schematic.

The Suppressor grid of the 6K7, that the small coil is connected to, acts as a small coupling capacitor to the 6K7's Anode. It is actually a brilliant idea, because its capacitance with respect to the Anode is a highly controlled parameter due to the tube's construction, rather than having to create a more temperamental small Gimmick capacitance. And the phase relationship of the small coil, to the coil driving the grid of the 6K7 is such that the feedback provides a small degree of Neutralization to the 6K7 stage.

Audio Output stage:

The 6F6 audio output stage can provide 3 Watts of output power and the sound of the radio is enhanced by the good sized wooden cabinet and an 8 inch electromagnet speaker. When I first got the radio, the Field Coil was open circuit and it required rewinding. This required driving out some spiral pins which attached the coil assembly to the speaker frame and some machining to release the coil. Then the pins were replaced with screws and nuts. A new Bobbin was made out of discs of Formica sheet and other materials.

The 3 Position Tone Control and the Fletcher-Munson effect:

The radio has a three position Tone Switch, combined with the power on switch. Stray hum injection which can occur when the ON/OFF switch is mounted on the rear of a Volume control can be a real problem in some radios. It is much better where Philco put it.

In this combined Power-On-Tone switch case, the hum signal injected into the Loudness tap via the 51k resistor is heavily attenuated. Assuming there was a capacitance between the power switch contacts and the Tone switch contacts, with a stray coupling capacitance as high a 60pF, the presence of the 0.006uF capacitor, in two of the Tone switch positions at least, would attenuate the hum voltage by about 100:1. And in one position the 0.006uF capacitor is shorted out eliminating hum injection by this route completely.

The Volume control has a Loudness Tap. This idea was invented in the 1930's due to the Psychoacoustic property of Human Hearing known as the Fletcher-Munson effect. Harvey Fletcher and Wilden Munson published their paper on Loudness Curves in 1933. Only five years before the the Philco 38-7 radio was made. It is interesting how quickly this concept and a solution for it got into electronics designs of the time. Later, more precise filters were added in audio systems with the loudness button. It is hard to determine who first modified the Volume Control Potentiometer in this manner with the loudness tap. Both RCA and Philco were doing it in the late 1930's.

Is essence at low range volume levels we perceive reduced Bass. The Volume Control's Tap normally has a shunt to ground RC filter. In the 38-7 radio it consists of a series 51k resistor part (32) and a 0.006uF capacitor part (38). This bypasses the higher range audio frequencies to ground, resulting in a relative or perceived boost in the Bass at low range volumes. It is a form of frequency shaping that is dependent on the position of the volume control.

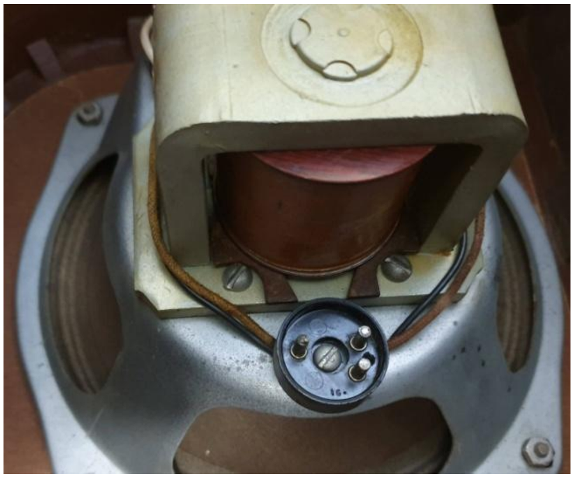
In the first position of the Tone switch, the 0.006uF Capacitor gets shorted out. The frequency dependent filtering, with a relative cut in high notes with respect to the Bass, or a higher Bass level than the trebles, is now converted to a flat response. However the 51k resistor is now shunting all frequencies equally. Therefore it appears from the radio user's perspective that the Bass gets cut.

In the second position of the Tone control, no frequency shaping is used. The apparent Bass boost at lower volumes from the loudness circuit remains. And in the third, most clockwise position on the control, additional capacitance is added to the Anode circuit of the 6F6, this has the effect of cutting the Trebles.

Rewinding the Speaker's Field Coil and the Inverse 4th Power Relation:

The Field coil in my radio was open circuit and required rewinding.

This is a common problem with vintage electromagnetic speakers. Other areas it crops up in are vintage Tube Inter-stage transformers with very fine wire. This is invariably due to Green-Spot Disease which is corrosion of the fine Copper wire. The vintage enamels did not protect the Copper as well as modern enamels, especially the modern Grade 2 variety. This problem, apart from making the coil go open circuit, makes it very difficult to count the orginal number of turns, because the wire breaks so easily in the corroded areas.



Re-Wound Philco 38-7 Field Coil.
Spiral Rivets replaced with screws/nuts.

There is something important to be aware of in re-winding field coils. In essence the situation revolves around filling a fixed volume bobbin with fine wire to a winding height closely resembling the original, with a matched wire size.

In this scenario the actual DC resistance of the coil that you end up with, after the rewind on the bobbin, is inversely proportional to the 4th power of the radius (or diameter) of the wire. It is one of those steeper “to the power of” relationships seen in other areas of Physics, in areas such as the field of Thermodynamics or Fluid Mechanics where 4th power equations are also seen.

This means, for example, if you doubled the diameter of the new wire compared to the orginal wire, the DC resistance will be 2^4 = 16 times lower than the original coil. Or if the wire used was half the diameter of the original wire, the resistance would end up 16 times greater. To drop the resistance by a factor of two, the wire size only has to increase by a factor of 1.2 or 20%, because 1.2^4 is about 2.

Mainly the target value for a field coil rewind on a vintage speaker is the original coil’s DC resistance. The exact inductance is less important because one wants the B+ voltage to be about the same as it was with the old Field Coil, with a similar voltage drop across the coil with the correct average power supply current. Though, the inductance is also affected in a similar manner to resistance, with a wire size change, it is also an inverse 4th power relationship for filling a fixed sized bobbin to some fixed height with wire.

In a nutshell, it pays for the rewind to measure the winding height and the original wire AWG or SWG size very carefully and stick to both those parameters for the rewind.

Now this is not to say that other parameters do not affect the DC resistance of the final result. For example how neatly or scrambled the winding architecture might be. The enamel thickness of the particular wire will have some effect. The wire’s winding tension affects the final result too. Or if the original bobbin was layer wound with thin paper between the layers, which the re-wound bobbin does not have. In this case there may be more wire turns in one dimension, in the winding height. The DC resistance could end up 10% to 15% higher than the original. But this is nothing as extreme as the inverse 4th power relation of changing the wire’s size.

If, on account of the new wire having more turns than the old wire, for the same winding height without thin paper inter-layer insulation being present, some wire can be unwound from the outer surface of the bobbin to correct for that, so that is not a drama.

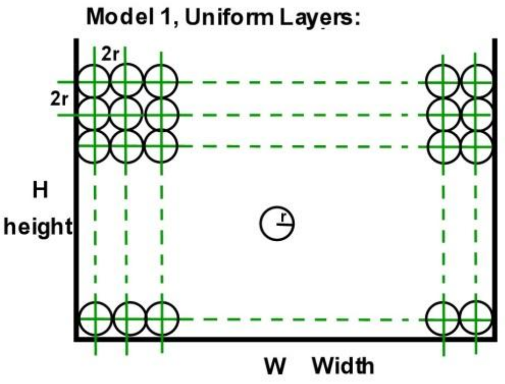
Fixed Geometry Bobbin Modelling:

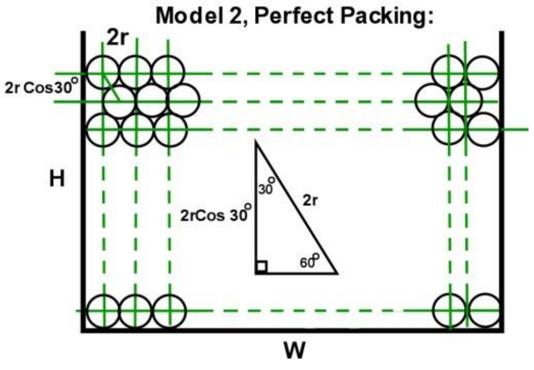
The reason for the inverse 4th power relations for filling a fixed sized round bobbin with wire and changing the wire size is that two squares are multiplied. The resistance of the wire itself is inversely proportional to the wires cross sectional area and that is proportional to the square of the wire's radius. And the turn's numbers that will fit in a fixed bobbin of some cross sectional area, is inversely proportional to the wire radius squared, this relation remains true regardless of the wire packing model used *.

The product of the turn's numbers and the average length of a turn (a constant related to the bobbin geometry) provides the wire's length. The total resistance is proportional to the length of the wire divided by the wire's cross sectional area. Therefore the two $1/R^2$ factors multiply to become a $1/ R^4$ proportional relation.

(*) There a number of models with correction factors, which can be used to calculate how many turns of a particular sized wire will fit into the bobbin's cross section. Regardless of the wire packing model imagined, the proportionality relationship holds, that the number of turns that will fit is is still inversely proportional to the square of the wire's radius. As noted below, for any fixed sized bobbin, if the wire packing was geometrically perfect, as Model 2 indicates, more turns of any specific wire will fit for essentially the same winding height.

In practical reality model 1, when used as a method to calculate a final resistance, gives a fairly close result, because of the nature of a jumble wound bobbin. The jumble wind also gives a result that is often fairly close to the original vintage uniform winding which may have had very thin insulation between perfect layers. If anything, the result using model 1, will have more turns and be a slightly higher resistance in the order of 5% to 10% higher, if the bobbin in filled to exactly the same height as the old wire and insulation, provided the wire size is the same. However, that is easily remedied by removing turns if required. It is better this way around, than having to join the wire and add turns to get to the target resistance.





$$\text{Turns } n = \frac{H}{2r} \times \frac{W}{2r} = \frac{HW}{4} \times \frac{1}{r^2}$$

$$n \propto \frac{1}{r^2}$$

$$\frac{HW}{4} = \text{Constant for Model 1}$$

$$\text{Tuns } n \text{ (approx)} = \frac{H}{2r\cos 30^\circ} \times \frac{W}{2r} = \frac{HW}{3.46} \times \frac{1}{r^2}$$

$$n \text{ is still} \propto \frac{1}{r^2}$$

$$\frac{HW}{3.46} = \text{Constant for Model 2}$$

Model 2 predicts approximately 15 % more turns possible than for Model 1.

Model 1 better predicts a rewind result- see text.

The same thing happens to the Inductance with a change in wire size, but for a different reason. Again the number of turns that will physically fit the bobbin is inversely proportional to the square of the wire's radius, and in the case of Inductance, its value is proportional to the square of the number of turns, so it becomes a $(1/R^2)^2 = 1/R^4$ relationship also.

Calculating the expected resistance:

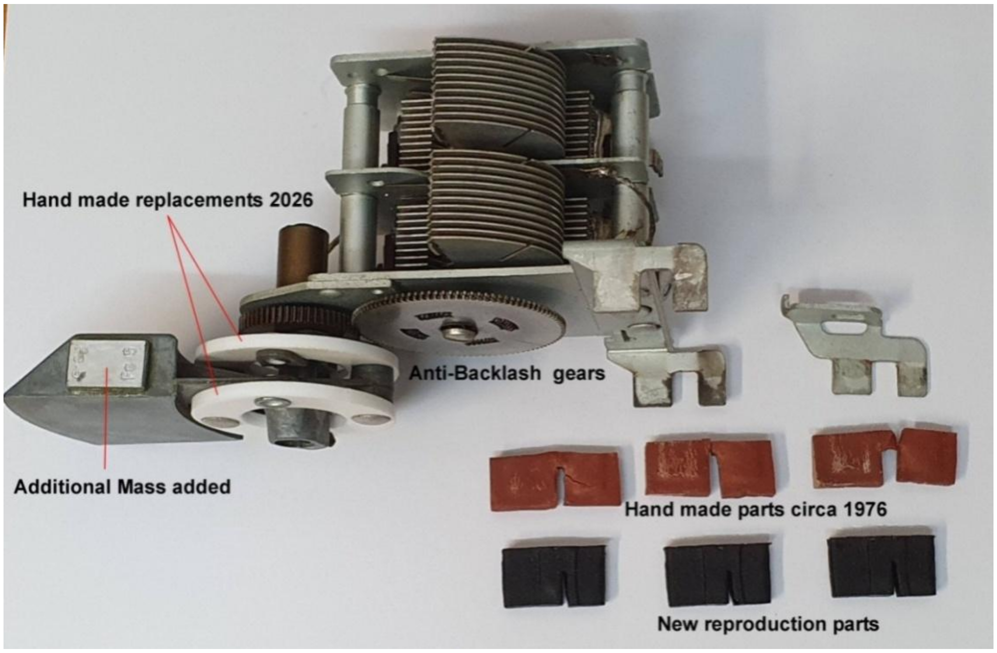
If the average turn length is measured (this corresponds to a turn's circumference at half the winding height because the turn length increases linearly with winding height for a round bobbin) and then multiply by the turns numbers (use model 1), this gives the total length of the wire, l, in meters. From the usual formula $R = P\,l/A$, where, R is the resistance, *P* is the resistivity of annealed Copper at 20 °C = 1.72×10^{-8} Ω.m and A the wire's cross sectional area in m^2 the expected resistance is easily calculated.

However at 60 °C expect a higher measured resistance because the resistivity figure increases to about 1.96×10^{-8} making the resistance about 14% higher when "hot" in other words, Copper has a positive temperature coefficient. Some radio manufacturers specified the Field Coil resistances when "HOT" so keep that in mind when checking what the original DC resistance was on the schematic.

Also when measuring the resistance of these sorts of coils, it pays to use an Analog meter. Some digital meters can play up when high inductances are involved.

Replacing worn Cracked and Damaged Rubber Parts:

Fortunately these days with the interest in vintage radio restorations increasing, reproduction parts are available for this radio. For example the Cloth over the speaker in this radio is an exact reproduction weaving to match Philco's original cloth, which has long since disintegrated. Also the rubber mounts for the variable capacitor have been reproduced along with the rubber feet that sit on the chassis corners, used on many other Philco chassis models.



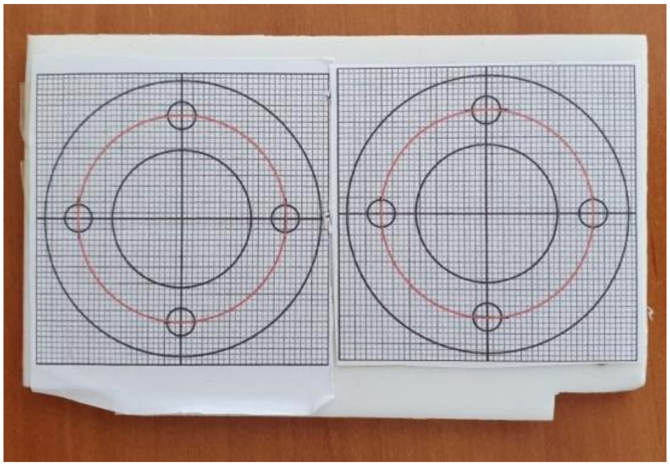
The tricky part was replacing the two hardened rubber discs in the variable capacitor’s coupler. They were riveted in place. And because the casting is a type of Pot Metal, it has to be done slowly and carefully to avoid damaging it.

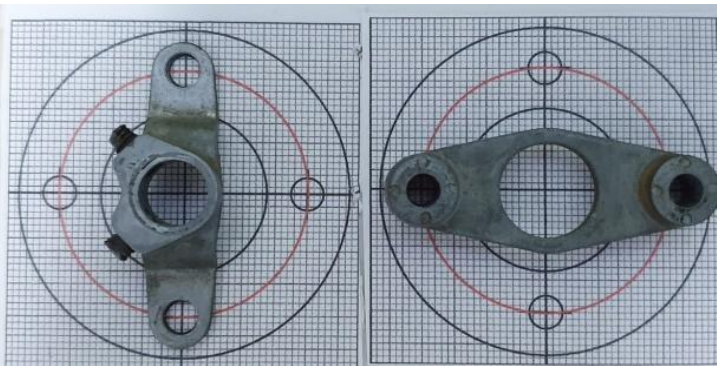
The photo below shows this coupler. The original rubber material was close to 1/8” = 3.175mm in thickness. I was also a three layer laminate with a twin fabric layer embedded in it.

To make new discs I chose to use a piece of 1/8” thick Teflon plate I had in my hardware collection. It was firm enough for the task but also flexible enough too. I came out of some disassembled medical machine in the past. It was just big enough to cut two discs from and there was no room for error.

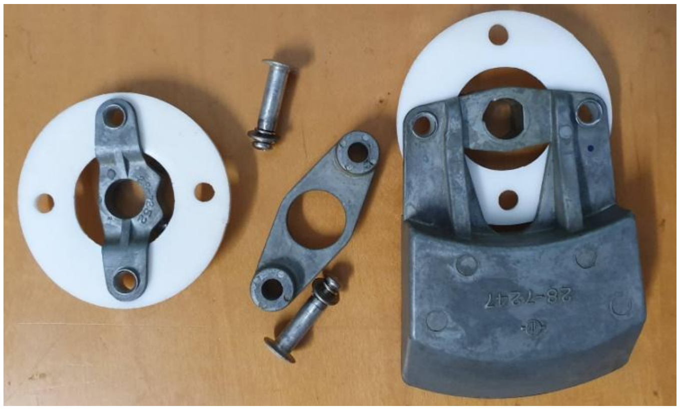
I did not have the correct sized hole punches on hand an had to buy a suitable punch kit.

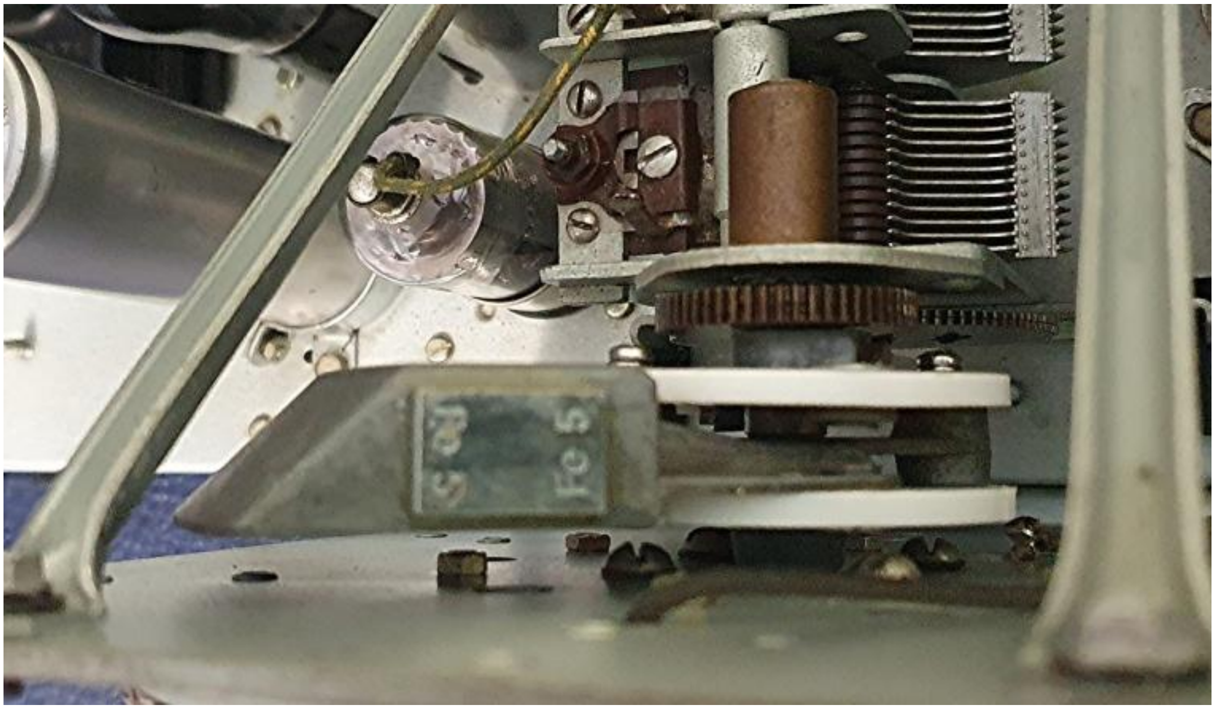
I decided to make an exact scale computer drawing on paper and use thin double sided sticky paper (called Jack Paper) to stick the paper diagram to the surface of the Teflon plate. This was so it would not slide around and it would help me as accurately as possible manually position the punches before deploying them. The punching was done in a large Vise, using an acrylic sheet as the backing for the Teflon, because it was stiff enough to support it for a clean cut, but not so hard that it damaged the sharp cutting edge of the metal punch. I checked that everything lined up before punching out the holes in the discs:





The photos below showing reassembly of the coupler:



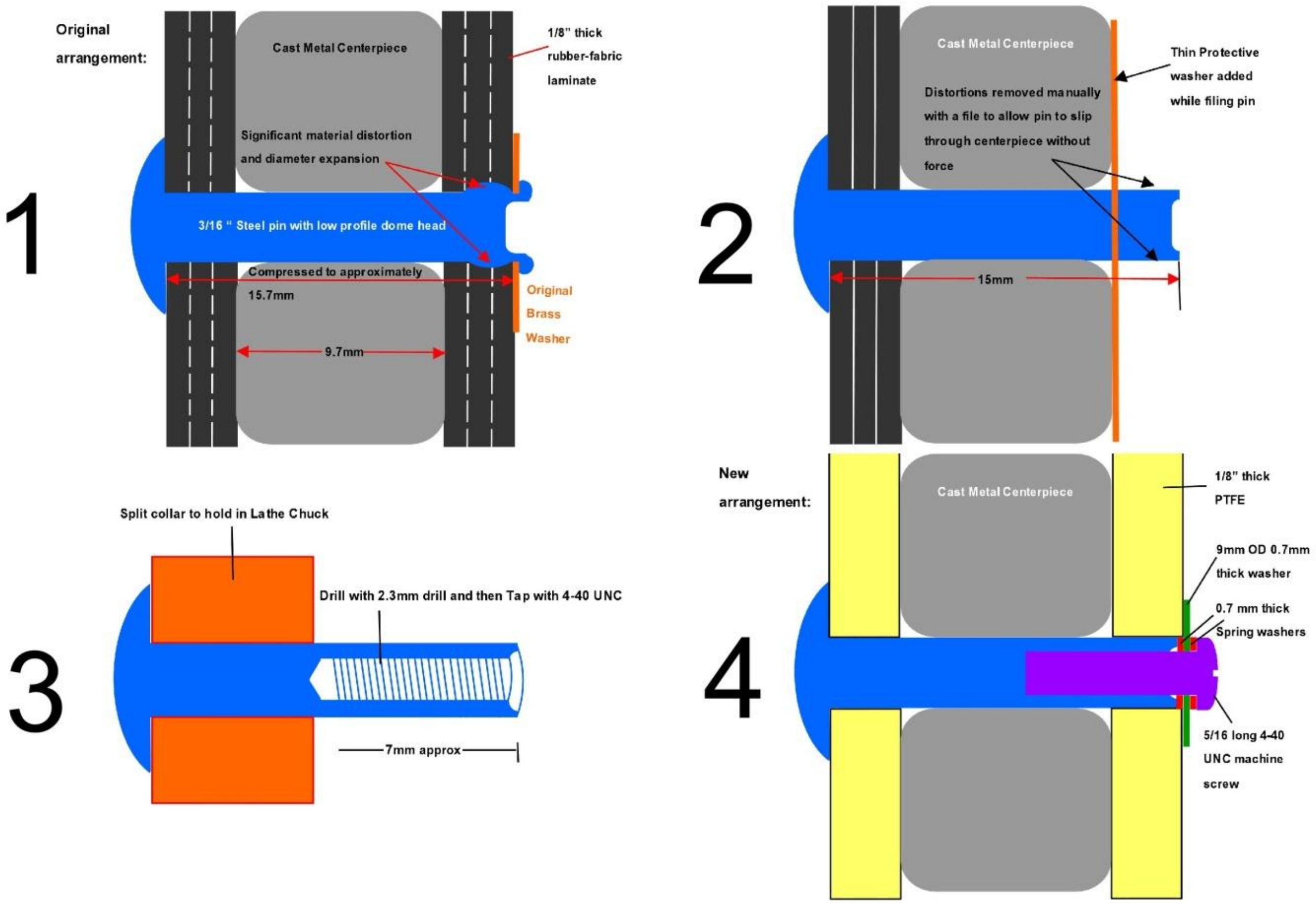


One thing that appeared over time, the counterweight had apparently lost some mass for a perfect balance with the other rotating parts. I cured that by attaching two 5 gram Iron weights (Car Tire balancing weights) to either side of the counterweight.

The diagram below shows how the coupler repair was done in more detail. One of the difficult aspects was to remove the bulge in the two long rivets (shown in blue) which occurred during the original riveting and manufacturing of the coupler by Philco.

I managed to preserve two of the long rivets by drilling them and threading those with 4-40 UNC threads so that the removed end could be replaced by screws. Also I found four suitable replacement eyelets for the other required parts.

I had to preserve these long rivets (shown in blue) because of their very low profile heads, which are required for clearance on the vertical plate holding the Cones. The bulge in their body prevented them from sliding through the hole in the casting after the peened over part was removed. These pins cannot be driven out with that bulge present, or the casting would crack. I applied a thin protective washer and patiently hand filed them down for clearance and smoothed them later in the Lathe.



I had to machine a split collar to hold the pin in the Lathe chuck for drilling, prior to taping the thread. It was basically a 4 step procedure. I cannot over emphasize the value of a Lathe in vintage Radio & TV restorations. I also use mine to rewind Transformers & Coils.

Alignment and Sensitivity Testing of the Philco 38-7 and Similar Tube Radios:

I am a great believer in having a controlled RF signal source with a good Attenuator and accurate frequency counting to test and align vintage radios. Even though precision RF generators and frequency counters did not exist in many service shops repairing Tube radios around at the time this radio was made. This can be an argument some use not to have to bother with such equipment. But, they might not know what they are missing out on. In all cases it pays to follow the manufacturer's alignment instructions faithfully, regardless of the quality of the signal generators in use.

I use the excellent Philips PM5326 solid state RF signal generator for this task. It has an inbuilt digital frequency counter and was designed for the alignment of AM and FM Radios. It covers 100kHz to 125 MHz. It has sweep functions to help with the alignment of TV IF stages and AM and FM detectors too. It is always better when the frequency is measured prior to the Attenuator inside the generator, not after it, because as the signals get very low in level, external frequency counters can struggle even with added amplification.

Many manufacturers of radios after the 1960's era provided a specific microvolt RF input level at the antenna and the associated audio power output level, such as 50mW, into a dummy speaker load. This data is very useful for checking the radio's sensitivity. However these figures were not often provided by the manufacturers of early Tube domestic radios. It therefore becomes a matter of knowing what to expect from a particular radios' design and tube line-up.

The sensitivity data, if provided, ideally should also describe exactly the way a specific RF generator's output, with its specific output impedance, was coupled into the radio's antenna input. This sort of useful data was often provided for Communications grade radios with an RF stage, along with detailed alignment instructions.

However, for many domestic Tube radios of yesteryear, not only was the sensitivity figure absent, the alignment instructions were often brief with poor detail. The maximum audio output power was often quoted, for example for the 38-7 model they quoted "Undistorted output: 3 Watts" on the schematic. Of course the distortion at full output power is not insignificant and typically for case like this, in the order of 10% 2nd harmonic distortion.

Therefore I take an approach to this problem that is somewhat similar to the Philosophy of the Pirate character Jack Sparrow in Pirates of the Caribbean, who remarked: "The only rules that really matter are these: what a man can do and what a man can't do"

In the case of the radio's performance with unspecified sensitivity data, I am interested in what the radio can do and what the radio can't do, at the threshold of usability of the radio with ***weak signals***.

Weak signal performance is where the system noise and the recovered modulation content of the carrier become subjectively equal on a listening test. Any signal level lower than this the noise starts to corrupt the recovered modulation to the extent that the modulation starts to become unintelligible. In the absence of other specific data, this is the test I deploy after a full alignment to check the radio's performance in this area.

I determine what RF input voltage level at the antenna, using a 30% modulated carrier, results in the 50:50 noise versus recovered modulation on a subjective listening test. Because any RF signal level much lower than the modulation won't be intelligible.

In the properly aligned Philco 38-7 with its usual 6A8 converter, the 50:50 signal & noise equivalence occurs at an RF input voltage of close to 10uV at frequencies below 12 MHz. In the high SW band area of 14MHz to 19MHz the apparent S/N equivalence is around 24uV. This is a typical value for a radio with a similar five tube count without an RF stage (not counting the interesting 6J5 detector/AGC stage which adds no gain) and a Pentagrid Converter. Most of the system noise is in the 6A8 converter tube which sets the limitation on sensitivity & noise.

To improve the situation, a tuned RF stage helps. And moving to a Triode Hexode converter such as a 6K8 or ECH35 as noted helps the sensitivity and the S/N ratio. Many Communications radios with an RF stage and a 3 gang variable capacitor have around a 2uV sensitivity for 50mW output.

SUMMARY:

The Philco model 38-7 radio ticks all of the boxes for a Tube radio from the late 1930's era.

The 38-7's industrial design is outstanding for a home appliance. The mechanical engineering is well above average for any domestic tube radio. The Dial itself and the tuning arrangements are work of Art and Science. It is hard to imagine how Philco could have done better with the design. The radio also provides wide range SW coverage in one band and the standard MW band. Due to the large speaker and wooden cabinet and capable 3 Watt audio output stage, the sound quality is excellent. The 38-7 is a sensitive and selective enough receiver on both the MW and SW bands where it easily resolves many weak Short Wave stations with a relatively short wire antenna.

Possibly, Philco could have gone to a three gang variable capacitor and another Tube to incorporate a tuned RF stage with improvements in selectivity & sensitivity. But of course there is a price point and each design upgrade costs more. And the radio's signal to noise ratio performance was primarily set by the 6A8 Pentagrid Converter.

There is little evidence of any significant practical defects in the 38-7's performance in use, except for the AGC issue on strong short wave stations with the oscillator's frequency pulling problem and somewhat reduced performance in the high SW band area. Using the ECH35 in lieu of the 6A8 improves those issues, but doing that is not a must.

Philco missed out on using RCA's new 6K8 Triode Hexode converter tube, as it appeared in 1938, the same year as the 38-7 radio was released. Philco would not likely have had time to deploy it and alter the documentation.

Philco incorporated new ideas and circuit innovations, as noted the Loudness Tap on the volume control to counter the Fletcher-Munson Effect. Both the innovations of the Pentagrid Converter itself and the publication of the Fletcher-Munson Loudness Curves happened only 5 years before in 1933. Philco were quick to catch on to new developments in Science & Technology.

Philco incorporated a creative delayed AGC circuit and a unique IF Neutralization circuit. They also elegantly executed their switched Tone control system avoiding any hum coupling issues from the Line power Switch. They were sensible enough to power the radio via a Line power transformer which avoided any Hot Chassis issues. And, importantly, the chassis can be earthed with a three wire Line cord. The radio could be supplied in 110V/220V options making it suited for export.

Overall, this radio has a blend of both form and function which is very difficult to beat.

Is the Philco 38-7 worth collecting? The answer is definitely a resounding yes. They do appear on eBay from time to time, mainly in the USA, but the occasional one in NZ and Australia.

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