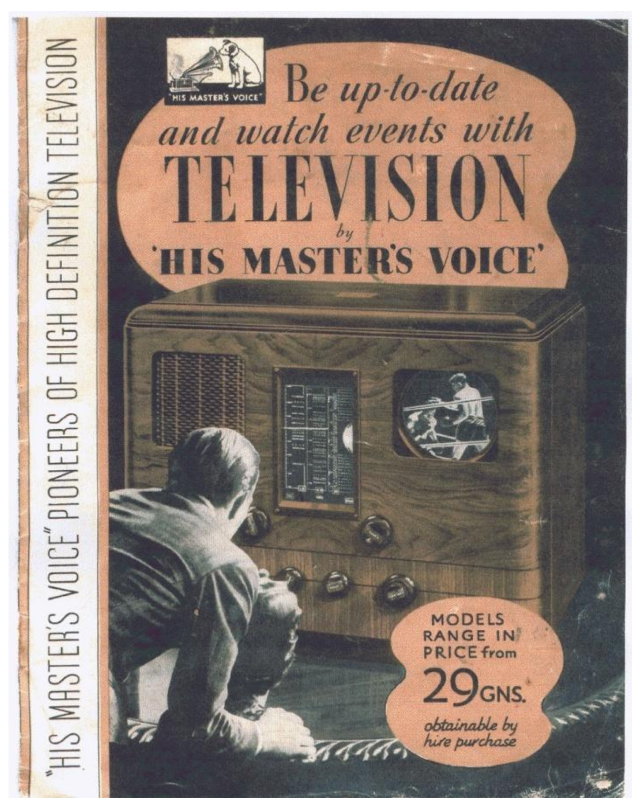
1939 HMV 904: A 5 inch pre-war Television Restoration.

Dr. Hugo. Holden.

INTRODUCTION:

The HMV 904 is 5” TV set, but in addition it’s a multi-band radio receiver. It was introduced in 1939 in the United Kingdom. The first image is my actual set. The other two images are advertising paraphernalia from the time.



BACKGROUND:

Electronic television technology was expanding rapidly on both sides of the Atlantic in the years leading to WW2. The BBC began transmitting in 1936, from a Hill in London, the “Alexandra Palace Transmitter”. The Palace housed the studio and the transmitter, and remained operational until a new transmitter was built in Birmingham in 1950.

The video carrier was 45 MHz, amplitude (AM) modulated, but with reverse modulation to the American system of the time: Synchronizing pulses reduced the carrier and white level increased it, opposite to the American system. The sound carrier was also AM with a carrier of 41.5 MHz and 6 dB down in level with respect to the video carrier.

The English EMI television system specified 25 frames per second, interlaced scan, 405 picture lines and as a result a field frequency of 50 Hz and line scanning frequency of 10,125 Hz. Many observers have commented on the audible whistle of the line output stages in British 405 line Television sets. Young people can easily hear over 10 KHz, with age the frequency response of hearing drops off. The modern British 625 line standard with the 15,625 Hz line frequency is beyond audible limits for many people.

The idea of restoring a 405 line set seemed very appealing. After comparing and contrasting two 1939 American pre war sets, the Meissner 5” kitset and the Andrea KTE-5, both with 5 inch picture tubes, it was really an irresistible idea to restore a British set of the time in order to experience the performance first hand.

THE HMV 904:

This television set is quite remarkable as it is also a 6 tube multi-band radio of very compact design. The radio tunes over 16.5 to 50 metres (short-wave), 200 to 570 metres (medium wave) and 725 to 2000 meters (long-wave) with a very elaborate dial and chain drive Vernier scale system. The set cost 29 guineas new and a 7 inch CRT version, the 905, was available for 35 guineas.

The tubes employed in the radio frequency stages of the set and local oscillator and audio stages are shared in both the television and radio modes. This is achieved with a fairly complex arrangement of intermediate frequency (IF) transformers, combined multi coil units and a very elaborate multi wafer band-switch. The IF transformer coils in the television section have large Brass tuning slugs and this technique results in a decrease of inductance of the coils they tune. There are no powdered iron cores or ferromagnetic cores in the inductors of the HMV904.

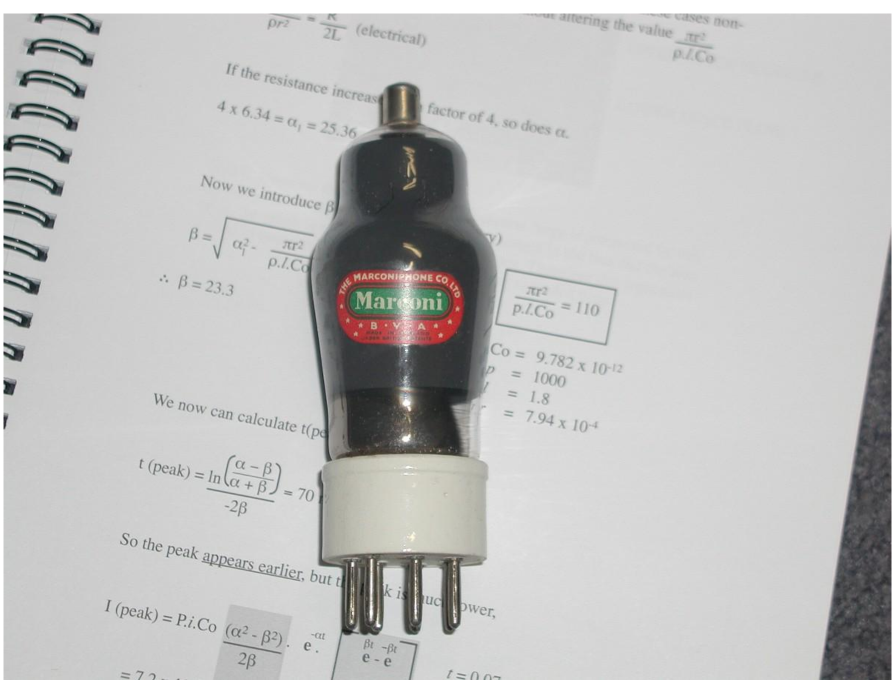
The 904 does have some unique circuit features, which will be discussed. These include the Frame output stage, the Line output stage (without a damper diode) and the very impressive “Anode Bend” detector/combined video output stage.

Firstly though, the 904 employs magnetic deflection for Line and Frame, and magnetic focus. Unlike two 1939 American pre war sets such as the Meissner kitset and Andrea KTE-5, which both employ electrostatic deflection and electrostatic focusing for example.

The tube types in the HMV904 will not be easily recognized by most American readers, as most don’t have USA counterparts, some do. The line-up is as follows:

1) Front end, MSP4.
2) Convertor X41C (ceramic base).
3) KTZ41 IF amp.
4) MHD4 Sound detector.
5) KT41 Sound output.
6) U52 HT Main Rectifier (=5U4).
7) KTZ41 IF television only.
8) KTZ41 Vision only.
9) MS4B Vision detector and video output.
10) KTZ63 Limiter (like a 6J7).
11) KTZ 63 frame Oscillator.
12) KT63 Frame output stage.
13) KTZ63 Line oscillator.
14) KT63 Line output.
15) U17 EHT rectifier.
16) D42 “pulse diode” used in the sync separator.

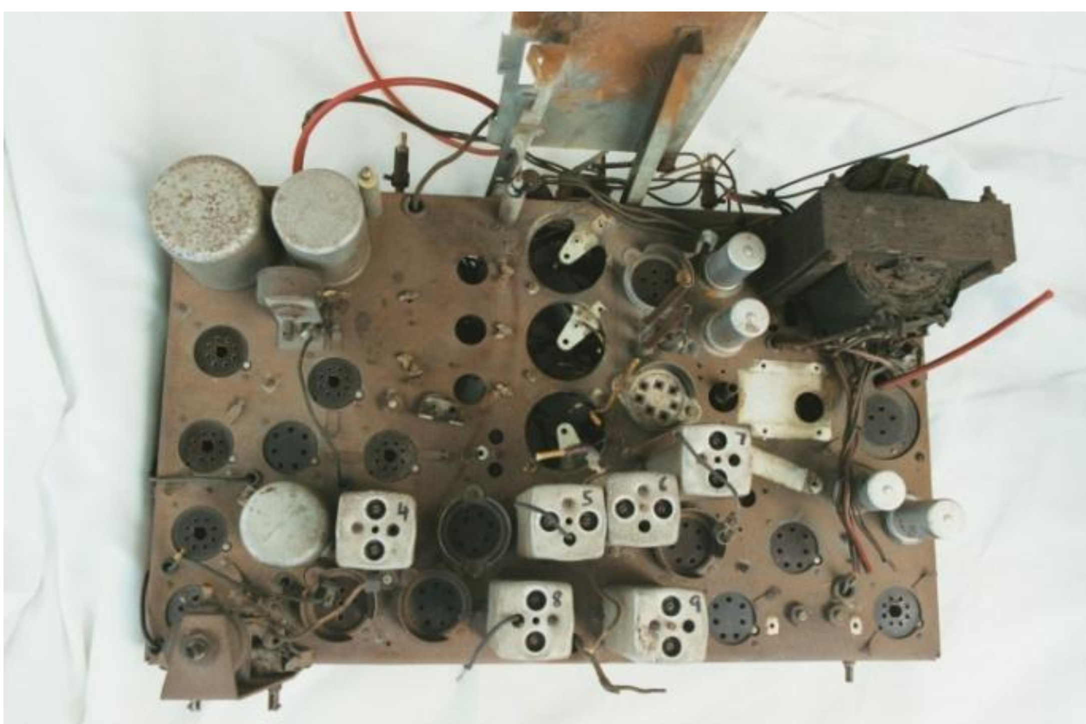
One of the most interesting and beautiful tubes is the converter, an X41C (ceramic base X41), the triode part of which forms the sets local oscillator that runs at 37MHz, below the received carrier frequencies of 41.5MHz (sound) and 45 MHz (vision):

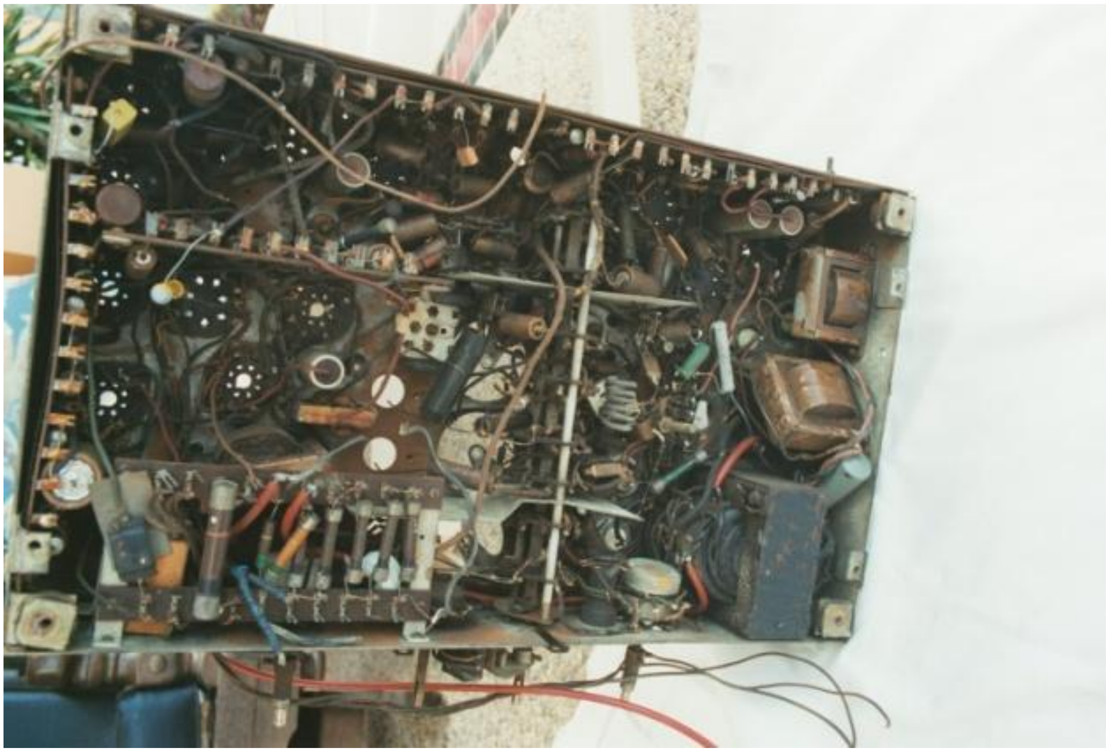


Usually a local oscillator runs the IF frequency above the received frequency, but this would have been too high for the X41. The X41 has similar electrical characteristics to an ECH35.

The set I have, less the cathode ray tube was acquired from the Early Television Foundation in the USA. They had acquired three, restored one for their collection and sold the other two. The set had a number of fairly severe problems. Firstly the CRT type "Emiscope 3/1" was missing. There was extensive chassis rusting as shown in the images below. Everything that was steel had rusted; mechanical parts, screws, bulb sockets small brackets etc.

There was moderate corrosion of all the aluminum parts. Underneath the chassis the wiring was disintegrating, in some places the insulation had turned to powder. A reminder of just how old this set was. Every wax paper capacitor was leaky, every electrolytic faulty and the tube sockets were corroded. Some of the resistors were still ok and fortunately all the important parts such as the RF coils, IF transformers and power transformers turned out to be ok. The main dial was in good order but the round Vernier dial very rusty with flaky paint. The cabinet would require complete refinishing. The two photos below show the set in the process off being disassembled, note the extensive surface rust:





The task began in documentation of the chassis wiring. Due to this set being a TV/multi band radio the switching is enormously involved and the wiring and component placing very crowded. It took almost two days to accurately document the wiring in the rotary switch areas and multi winding coils to ensure an accurate rebuild.

The set was then stripped down completely. The chassis, brackets, multiple rusted mechanical parts, including the variable capacitor frame (from the radio section) and bulb sockets were all fine bead blasted to remove all traces of rust and electroplated with the process of “electro-less nickel”. I have a preference for this because it electroplates into corners and down holes, so is excellent for complex shaped objects. It has a great satin silver metallic look to it, resembling the original plating and has excellent longevity. This can be further improved with a coat of clear lacquer, preferably VHT and then an oven bake. It was not practical to re plate the hundreds of rusty screws in this set. So I obtained new ones of identical geometry and original BA threads, which were readily available.

The aluminum components were polished and lacquered for protection. The tube shields were a composite of steel and alloy, were treated with rust convertor and ultimately after a lot of preparation painted with fine silver lacquer. The yoke and focus coil assembly also received the same electroplating process but were again painted with black lacquer to match their original finish.

The Vernier dial was repaired by scanning first, re-plating and re painting it. Then I doctored the image in Photo Studio software and printed out a replacement scale to apply to the repainted dial.

The Electrolytic capacitors were replaced and the wax paper capacitors re-built with new caps placed inside and the ends sealed with polyester resin. The large EHT filter cap was also re-built. The original tube sockets were corroded and unreliable, so I replaced them all with high quality ceramic vintage sockets, which after a lot of hunting turned up in the UK.

Finally the set was reassembled with the original under chassis layout and original Tag boards with the re-built capacitors and many new resistors too. A few of the original resistors were still ok. A set of NOS tubes again purchased in the UK, were fitted.

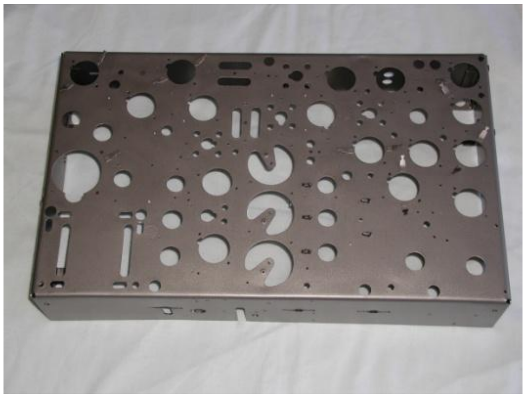
A few challenges lay ahead:

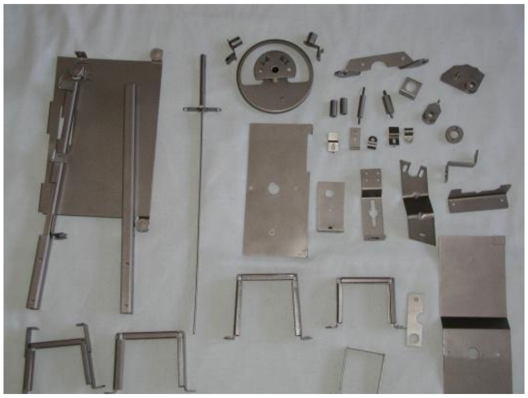
1) The electrical alignment of the set.

2) What to do about the missing CRT.

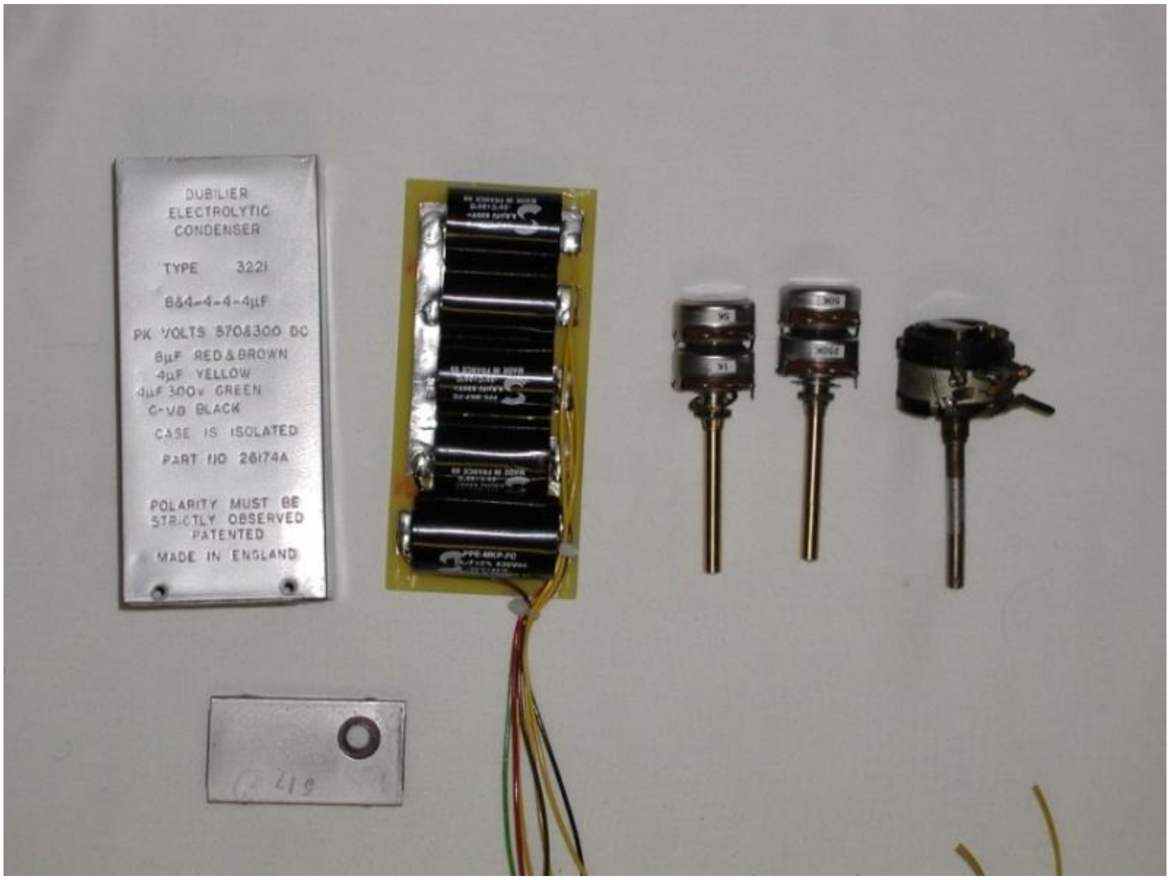
3) How to get a suitable 405 line signal source modulated on to the correct carriers now that the Alexandra Palace was no longer in business. As for the cabinet restoration, well that was truly last on the list.

The photos below show some views of the post restoration chassis. The first is the chassis & other parts back from the Electroplater:

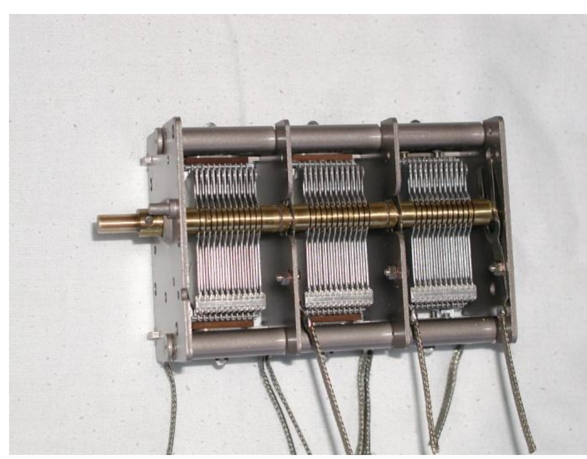




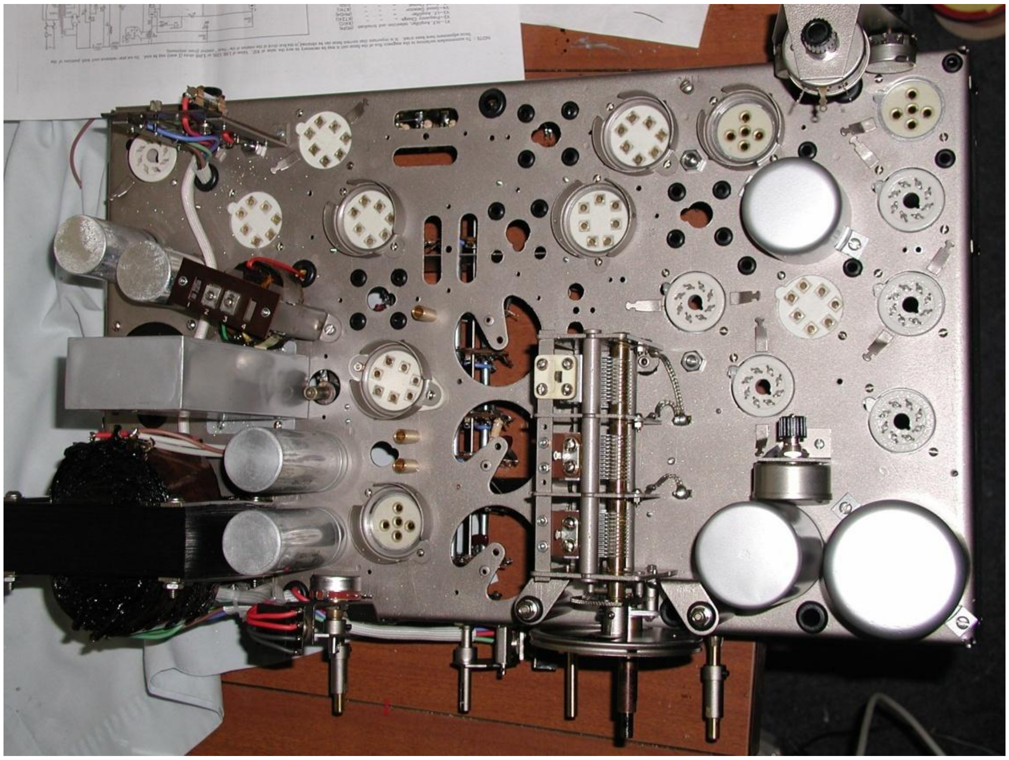
New capacitors placed in old container:



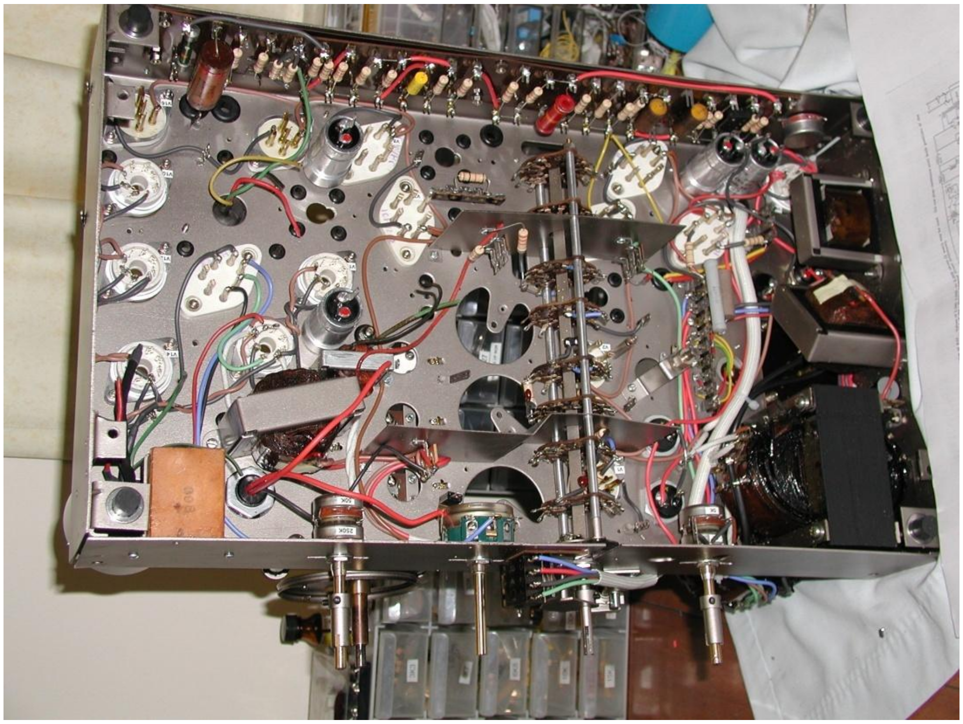
Two of the dual gang dual shaft potentiometers needed to be manufactured to replace the originals that were totally worn out. It was possible to fit high voltage non-electrolytic capacitors of the same value and higher voltage than the original Electrolytic capacitors that lived inside the rectangular can. These were mounted to a flat PCB to keep them in an orderly configuration.   Chokes/transformers/variable capacitor restored:



Chassis during rebuilding: The original tube sockets were replaced with NOS ceramic sockets:

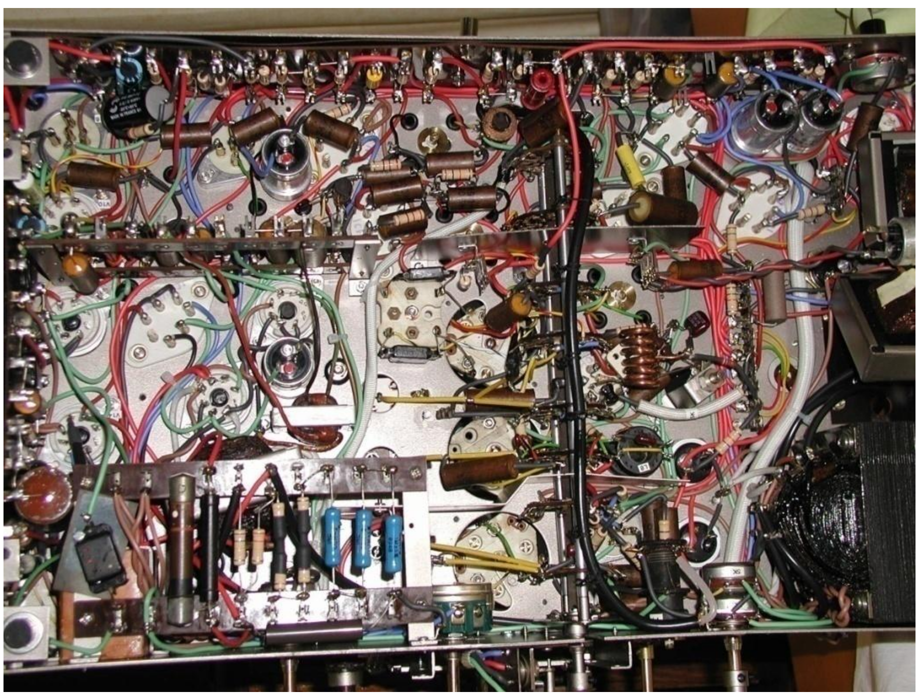


The new hookup wire is silicone rubber covered wire which is extremely heat resistant and as it happens closely resembles the appearance of the original rubber covered wire:



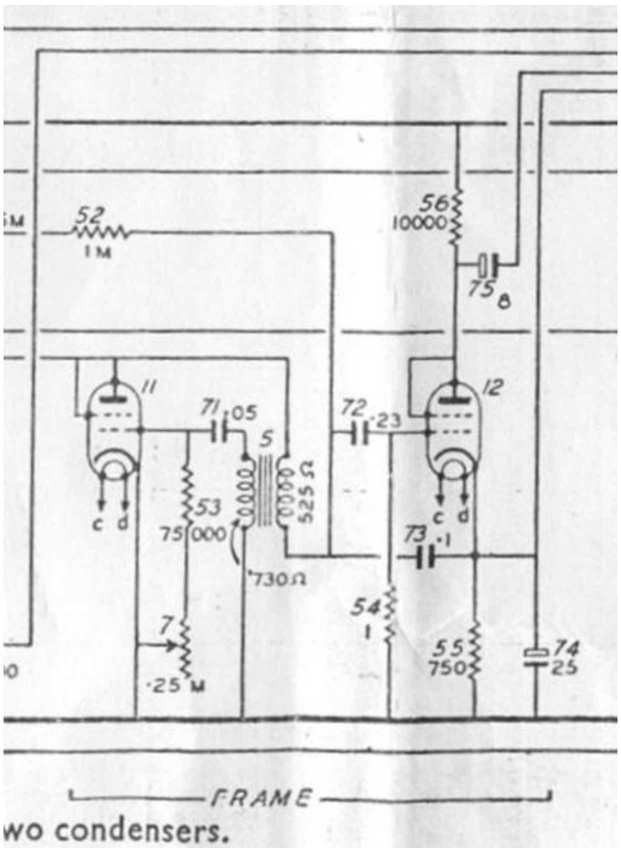
The restored chassis undergoing lab testing, the CRT is a 5FP4 see below:

The underside of the restored chassis:

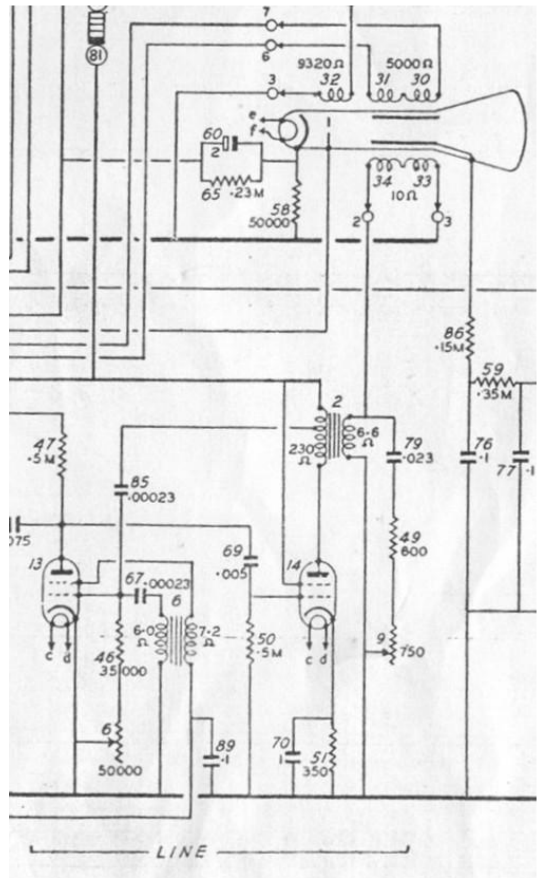


INTERESTING CIRCUIT FEATURES in the HMV904:

Frame Output Stage circuit:



Line Output Stage circuit:



The frame Output Circuit:

The Frame (vertical) deflection yoke in this set has a relatively large number of turns and a high DC resistance of 5K. The output tube's (V12) anode load is a 10 K carbon power resistor (R56). The yoke is coupled to the anode by an 8uF electrolytic capacitor, C75, from the anode of V12 and returned to the cathode of V12. The load, unlike modern magnetic deflection circuits, is very dominantly resistive, not inductive & reactive. The anode voltage waveform in this set is nearly perfectly saw-tooth in character to produce a saw-tooth scanning current. (When the load is partially reactive the correct drive waveform is trapezoidal, ie, a combination of a saw-tooth and a rectangular wave to result in saw-tooth scanning current). The plate resistor they have used is very inefficient however it does provide a satisfactory degree of damping and doesn't occupy much space and obviously an inexpensive option compared to the usual frame output transformer.

Line Output Stage circuit:

This is an interesting stage based on V13 and V14. The blocking oscillator is configured in the screen grid circuit of V13 and the output derived from the plate to drive V14. Feedback from the output transformer to the oscillator transformer via C85 appears to assist rapid fly-back. The output transformer core can just run satisfactorily at 10,125 Hz.

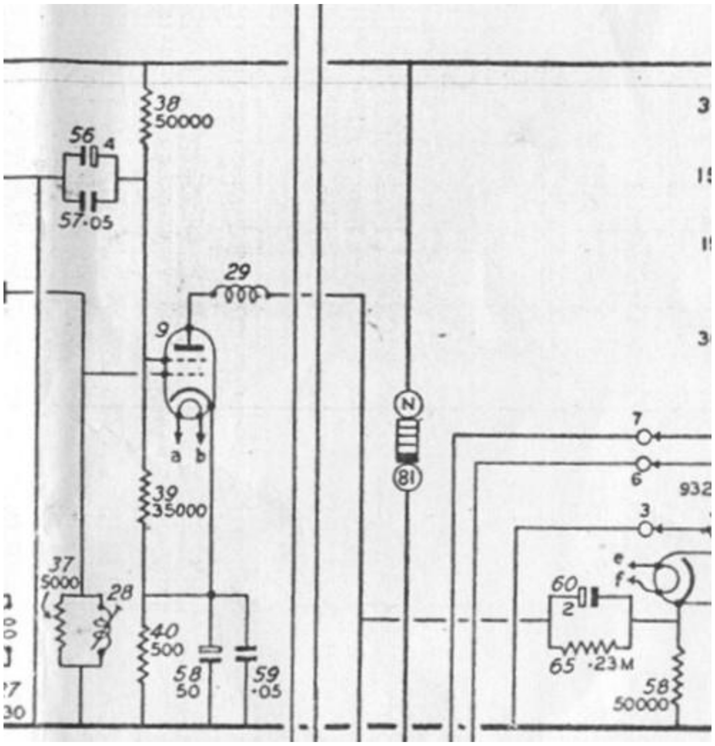
If this Line circuit is set to run faster (15,625 Hz for example) the linearity suffers badly with compression of the left side of the raster. The line yoke coils have a very low DC resistance around 11 ohms, and represent a very inductive load. There is no damper diode and the damping is merely resistive. This damping and to a degree the linearity, is adjusted by a control labeled "Form" R9 in the circuit. Despite this, the linearity on the correct scanning frequency is quite acceptable.

It appears that the first person to postulate the use of the damper diode, in 1936, in the UK, was Alan Dower Blumlein, the "inventor" of stereo audio. He patented "binaural audio recording"in1931. Blumlein was killed in a plane crash in 1942 testing radar. His death was described by Winston Churchill as a national tragedy.

Damper diode function was very well examined by RCA laboratories, (post war period), in an article by Otto. H. Schade. ref.(1) In this article reference is made to Blumlein's original patent for a non- linear deflection circuit with diode, 1936.

Over the years "efficiency diode" or "booster diode" became synonymous with damper diode. In these early years it became obvious that magnetic deflection circuits really only need be energy control/management systems. In deflecting a beam about center no overall energy would be required, only enough to overcome losses. This is analogous to a swinging pendulum, requiring small amounts of additional energy per cycle to keep in going. Despite the early work by Blumlein in the UK, the damper diode concept had not found its way into the HMV 904. See the article about damper diodes on the worldphaco.com site.

Detector/video output stage:



This is based on the MS4B,V9, a metalized glass Tetrode which is biased to be an Anode Bend power detector. (diagram above). This is the first time I have encountered this in a television set. It is a very good idea. The anode is direct coupled via L29 C60 and R65 to the CRT's cathode.

In effect V9 is biased as a class AB amplifier. The no signal plate current is very low compared to its class A counterpart used in most television sets. This saves power loss in the anode load resistor (not seen the diagram above).

The grid is of V9 is driven directly with the video carrier and the positive half cycles of the carrier are preferentially amplified due to the bias conditions being set for that mode. The carrier is filtered off by L29 and the associated capacity of the components and cathode circuit of the CRT. Oscilloscope analysis of the detected and amplified video shows it to be excellent and 25 to 30 volts peak to peak video without any difficulties.

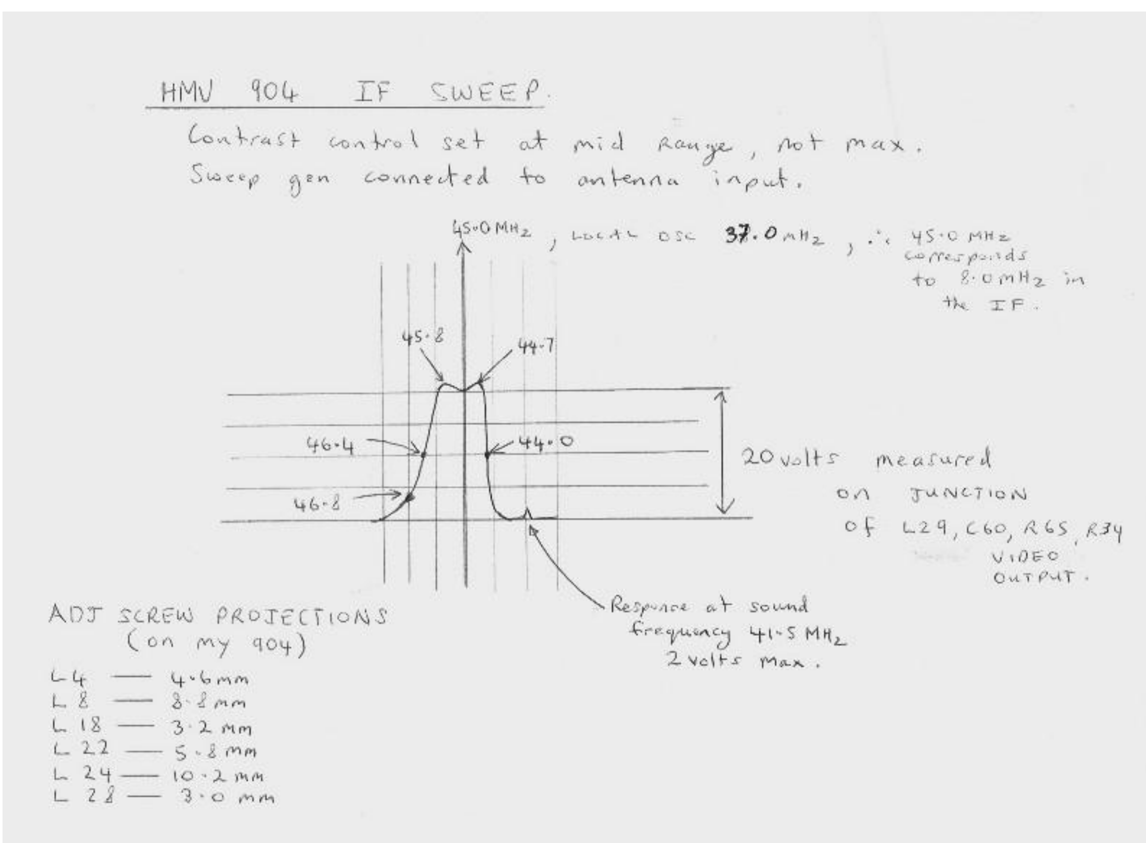
ELECTRICAL ALIGNMENT:

Following the manufactures advice in the manual I set up the RF, oscillator and IF stages, first the radio section and then the television section. Due to the sound and vision IF being common there is interaction between the two and when one is adjusted the other must also be reset.

After completing the alignment I swept the response of the set in the usual way, and much to my astonishment found that the intended video IF bandwidth was only 1.4 MHz. Despite this the screen image on the 5 inch tube was just acceptable. With a few minor adjustments and the use of the sweep generator I was able, without any modifications, to get the bandwidth to 2.4 MHz. This substantially improved the picture detail and lowered the overall gain a little but there was plenty of gain to spare.

It also became obvious right away that the magnetically focused 5FP4 is superior to both the 5BP4 and 5AP4 in USA pre war sets such as the Meissner and Andrea KTE-5 respectively. The latter tubes tend to lose focus as the beam intensity increases or is varied. This is due to the influence of the grid voltage on the beam and changing relative potential with respect to the focus electrode. The 5FP4 on the other hand maintains excellent focus at all beam intensities, however as the set warms up with time the focus coil current changes a little and requires re adjustment with the front panel focus knob from time to time. I don’t think constant current sources were on people’s minds back then.

The following sketch is a copy of the Oscillogram from a sweep of the 904 with an RF sweep generator on its input and a scope on the video output:



This band-pass characteristic was obtained without any circuit modifications, simply by the existing adjustment screw points. To assist others in initial alignment of this set I have also documented how far the adjusting slugs projected from their fixing nuts.

When set as per the above characteristic, the combination of overall gain and frequency response was perfectly satisfactory and resulted in the screen photo images shown in the pictures below, on a 5FP4 CRT.

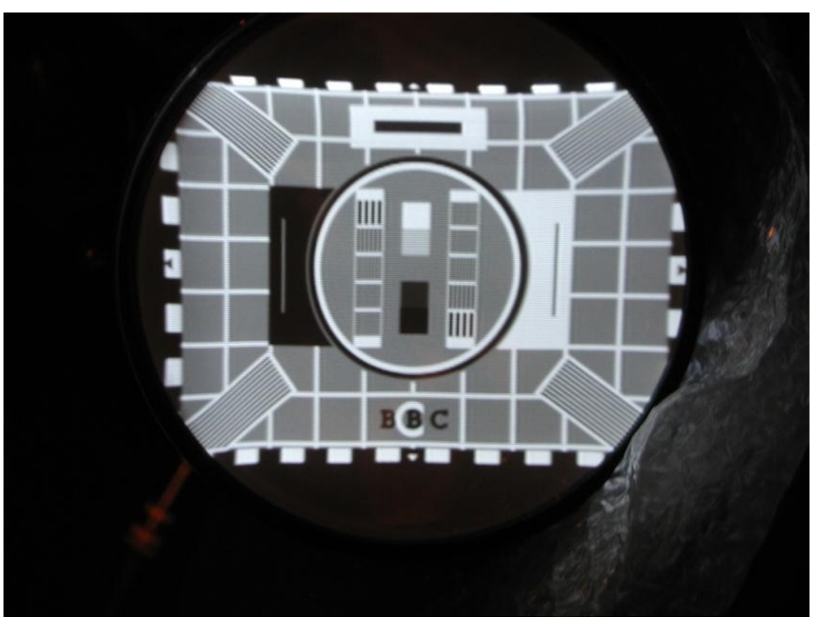
SUBSTITUTE CRT:

A replacement Emiscope 3/1 CRT could not be found. One fellow in the UK told me he had been looking for one since the late 1950's and had no luck. Some were found later but with fairly low emission.

Steve McVoy of the Early Television Foundation suggested a 5FP4. This, like the 3/1 is a 5" magnetically deflected, magnetically focused tube that was designed post war by RCA for the viewfinder on the TK30 camera. Also, importantly, this tube, as per the original is a non Aluminised tube, which is very important with the low EHT voltages. Aluminised CRT's require > 5Kv to 7Kv anode voltages. The radar 5FP7 version dates from 1942.

I located some 5FP4'sand started testing. The neck on the 5FP4 is a little larger than the 3/1, but removal of a small amount of cardboard from the center of the yoke allowed it to just slip over the neck of a 5FP4. The 5FP4 makes an excellent substitute, see un-retouched screen image photos below. The 5FP4 tube specs suggest a minimum EHT voltage of 4000V. I have had no difficulty running it on the 2400V in the 904. See separate article on www.worldphaco.com on the modifications required to fit the 5FP4.

The photos below are un touched up screen shots of the set working. The test pattern originates from David Grant's converter board. The lower photo started out as a freeze frame image from a Pal camcorder and passed through the 625- 405 converter.

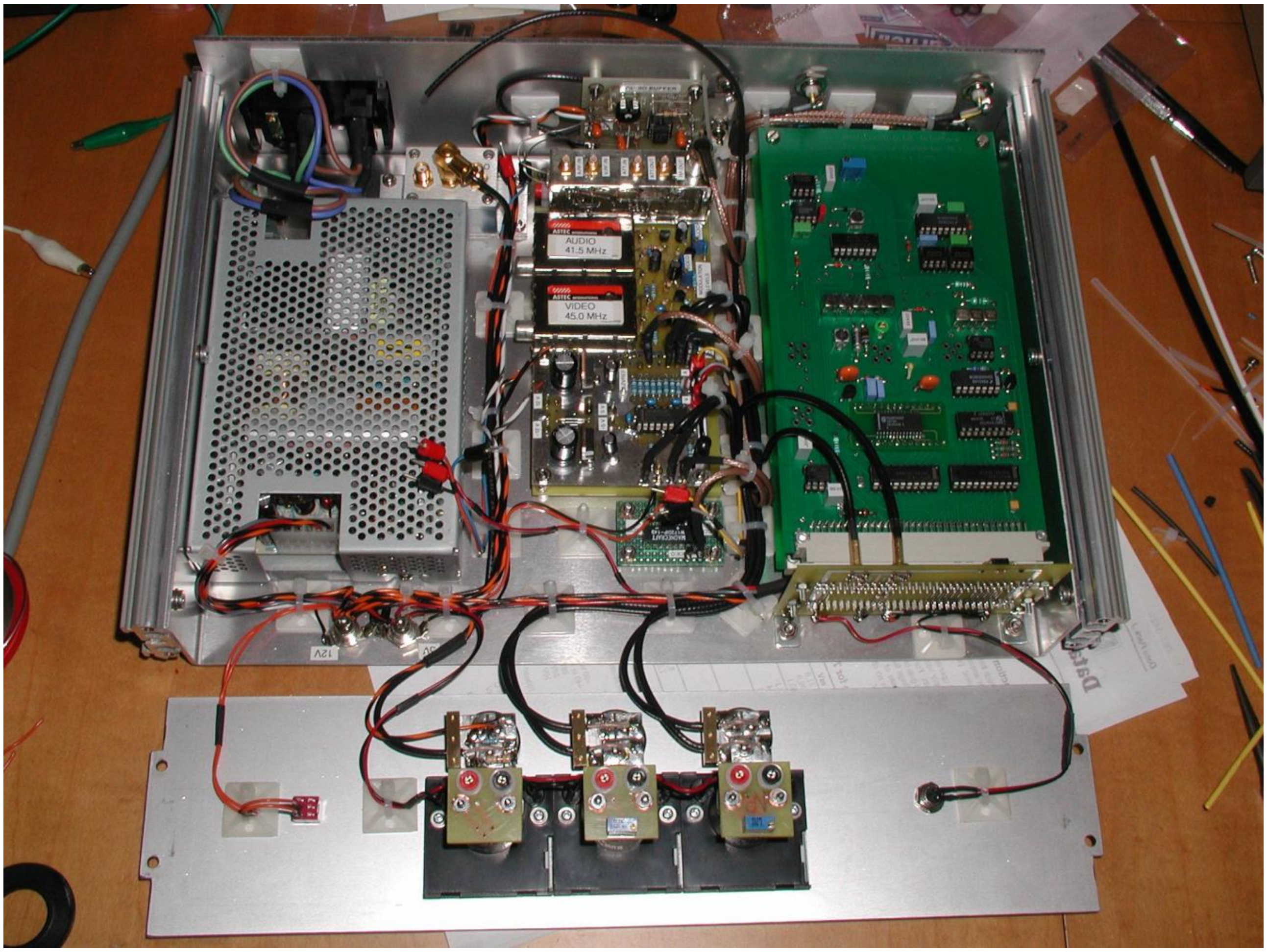


405 LINE SOURCE AND STANDARDS CONVERTER:

Vintage television collecting is becoming quite popular in the UK. A few talented people have turned their hands to making standards convertors. These receive a 625 line video source, basically digitize it and download it to memory and then read it out at the lower 10,125 Hz line rate. I acquired a standards convertor as a set of two boards and small motherboard from David Grant in the UK. This converter also has an on board test pattern generator.

I designed and built my own modulators modifying some existing Aztec units for crystal control and providing appropriate clamping and polarity inversion for the video. In addition a mixer amplifier and mini circuits RF attenuator was used to control the RF levels.

This unit effectively recreates the signals generated by the original Alexandra Palace transmitter. The unit can provide up to 14 mV rms RF out into 75 ohms, but in practice 3mV is a suitable level for the 904. Photographs of this unit are shown below including mixer-amplifier unit I made to mix the Audio and Video RF carriers and control the output level. The Two RF modulator units are Aztec units, which were modified for crystal control at 41,5 and 45MHz:



The green board/s on the right are David Grant’s converter boards. The middle boards are the video conditioning, RF modulators and mixer assembly. The switch mode PSU is on the left.

The mixer/amplifier/attenuator/RF level detector –meter driver was hand crafted into an empty larger Aztec modulator case.

The photo below is the finished converter (top lid removed) built into an OKI case, with the same output signals as the original Alexandra Palace transmitter in 1939:

Another separate 625- 405 converter unit was built: This one has the RF level metering rather than a calibrated panel control.

CONCLUSION:

The overall performance of the 904 is very good. The radio section is an excellent performer too. The CRT image is quite acceptable despite the relatively low bandwidth, primarily because on a 5” CRT the lower resolution is not as noticeable. The benefit of magnetic focus is obvious, so despite the poorer IF bandwidth compared to the Andrea and Meissner 5” 1939 TV sets, the overall picture is comparable over a range of contrast settings on the three sets.

The sound on the 904 is very impressive. These prewar TV sets have a relatively wide bandwidth in the sound channel compared to standard AM transmissions on medium or short-wave. The audio quality to me is indistinguishable from FM sound in modern sets. The effect is enhanced by the usual Class A audio output stage and good sized wooden cabinet with a permanent magnet 6 inch speaker in the 904.

I have no doubt that the deflection coil and focus coil assembly and the line output transformer in the 904 would have been more expensive to produce than using electrostatic deflection. This may have been compensated for a little with the simpler magnetically deflected CRT. On the other hand the 5AP4 and 5BP4 CRT’s with their more elaborate gun structures probably cost more than the Emiscope 3/1 or the 5FP4 to produce, but probably not by a great deal.

Ultimately magnetic deflection was to win out over electrostatic. Primarily this was due to the difficulties of acquiring high enough linear saw-tooth voltages as the EHT was increased for larger tubes. Linear amplifiers producing them would have to run off very high HT voltages: In electrostatic deflection the amount of deflection is inversely proportional to the EHT (final anode voltage). So if you double the EHT you need double the deflection voltage for the same width/height. In magnetic deflection the amount of deflection is inversely proportional to the square root of the EHT voltage, ref(2). So if you double the EHT voltage then you only require a 1.41 increase in the deflection current for the same width/height.

Finally one cannot be unimpressed by the level that television technology had reached by 1939. Viewing programs on these sets is an experience not a great deal different from observing them on any black and white television manufactured decades later.

Dr. Hugo Holden.

References:

1) Magnetic Deflection Circuits for Cathode-Ray Tubes, by Otto. H. Schade. Television Volume V 1947-1948, RCA Review, Radio Corporation OF America, RCA Laboratories Division, Princeton New Jersey. Pg 105.
2) Basic Television, Second Edition, Grob. McGraw-Hill Book Company, INC. NY, 1954. pg 48.