VINTAGE TELEVISION

By Dr Hugo Holden

The 1939 HMV 904 5-inch TV set

This is a most remarkable vintage TV set. Introduced in the UK in 1939, it combined a 5-inch TV set with a 3-band AM radio receiver. It really was a pioneering design and was sold as a "High Definition Television" using the then standard 405-line transmission standard.

The first TV receivers were based on 5-inch cathode ray tubes with electrostatic deflection, as used in oscilloscopes but shortly after BBC TV broadcasts started, this HMV set was introduced with a magnetic deflection yoke. It is very rare. At last count, there were only about 20 to 30 of this set known to remain.

The 405-line standard used a 45MHz amplitude modulated carrier but different to the American system of the time; synchronising pulses reduced the carrier and it increased with the white level. The sound carrier was also AM at 41.5MHz and 6dB down in level with respect to the video carrier.

The English EMI television system specified 25 frames per second, interlaced scan, 405 picture lines, giving a field frequency of 50Hz and line scanning frequency of 10,125Hz. This produced a very audible whistle to anyone with normal hearing, compared to the later 625-line system (as used in Australia) which had a line frequency of 15,625Hz (still audible).

While it may seem like a very big challenge, I found the idea of restoring a 405 line set very appealing, to experience the performance first hand. The more one looks at this unit, the more remarkable it seems.

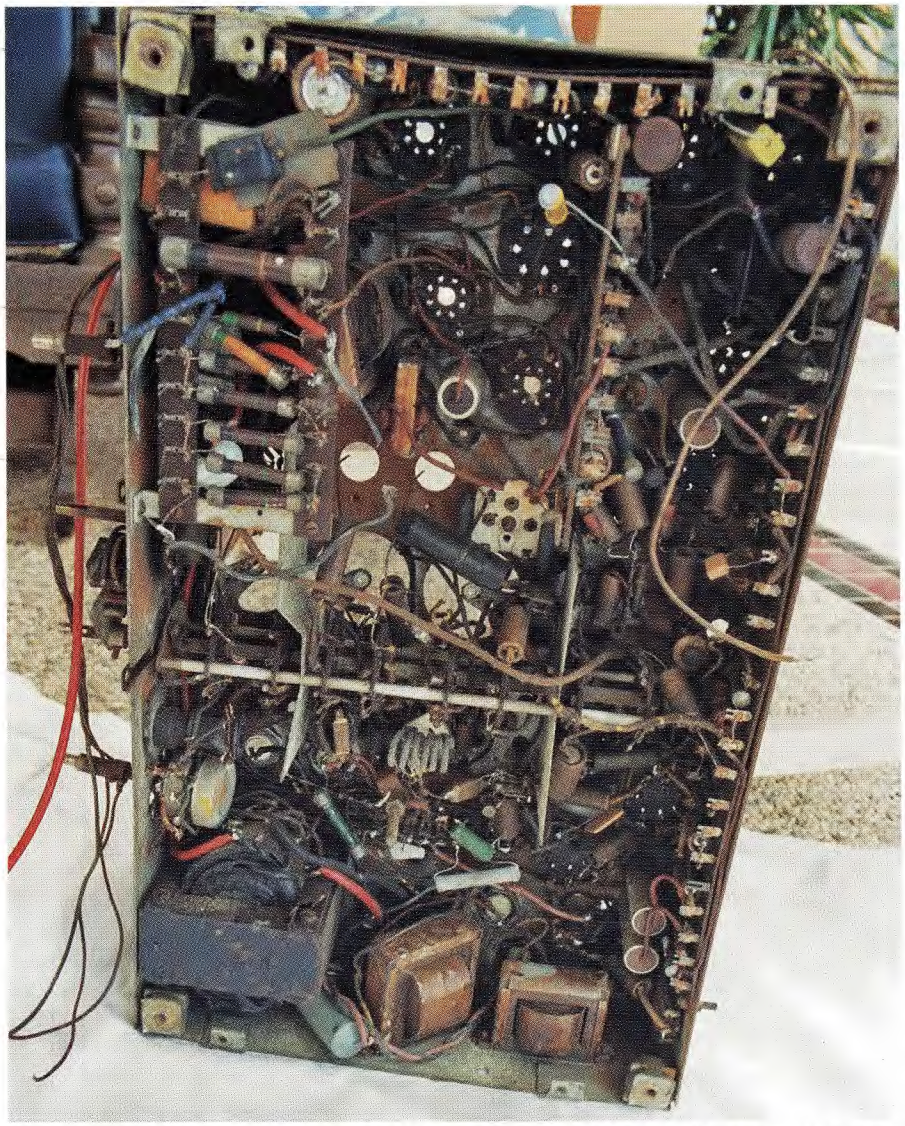
As already noted, it is also a 6-valve multi-band radio which tunes over 16.5 to 50 metres (short-wave), 200 to 570 metres (medium wave) and 725 to 2000 meters (long-wave) with a very elaborate dial and chain drive vernier scale system.

The 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 in inductance of the coils they tune; there are no powdered iron cores or ferromagnetic cores in the inductors of the HMV 904.

As well, the HMV 904 has some unique circuit features which include the vertical output stage, the horizontal line output stage (without a damper diode) and the very impressive "Anode Bend" detector/combined video output stage.

No less than 16 valves are employed. One of the most interesting and beautiful tubes is the converter (V2), an X41C (ceramic base X41), the triode part of which forms the set's local oscillator



The underside of the unrestored HMV 904 chassis with the valves removed. Due to the age of the set, it's no surprise that it had rusted quite significantly.

on all the aluminum parts. Underneath the chassis, the wiring was disintegrating and in some places the insulation had turned to powder; a reminder of just how old this set was, at almost 80 years!

Every wax-impregnated paper capacitor was leaky, every electrolytic faulty, and the valve 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 functional but still required restoration.

The main dial was in good order but the round vernier dial was very rusty with flaky paint. The cabinet would require complete refinishing.

The task began with the documentation of the chassis wiring. Due to this set being a TV/multi-band combination, 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 then electroplated with the process of "electro-less nickel". I have a preference for this because it electroplates into corners and down holes, so it is excellent for complex shaped objects. It has a great satin silver metallic look

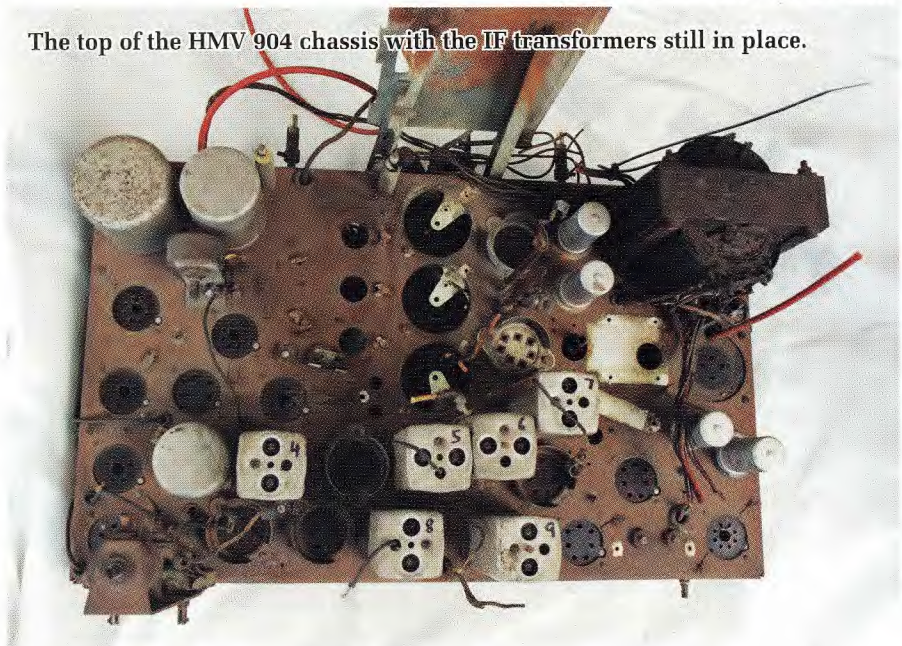
that runs at 37MHz; below the received carrier frequencies of 41.5MHz (sound) and 45MHz (vision).

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

My set was acquired from the Early Television Foundation in the USA. They acquired three, restored one for their collection and then sold the other two; one to me. The set had some fairly severe problems. Firstly, the "Emiscope 3/1" type CRT was missing. There was very extensive chassis corrosion. In fact, everything that was steel had rusted; mechanical parts, screws, bulb sockets small brackets etc.

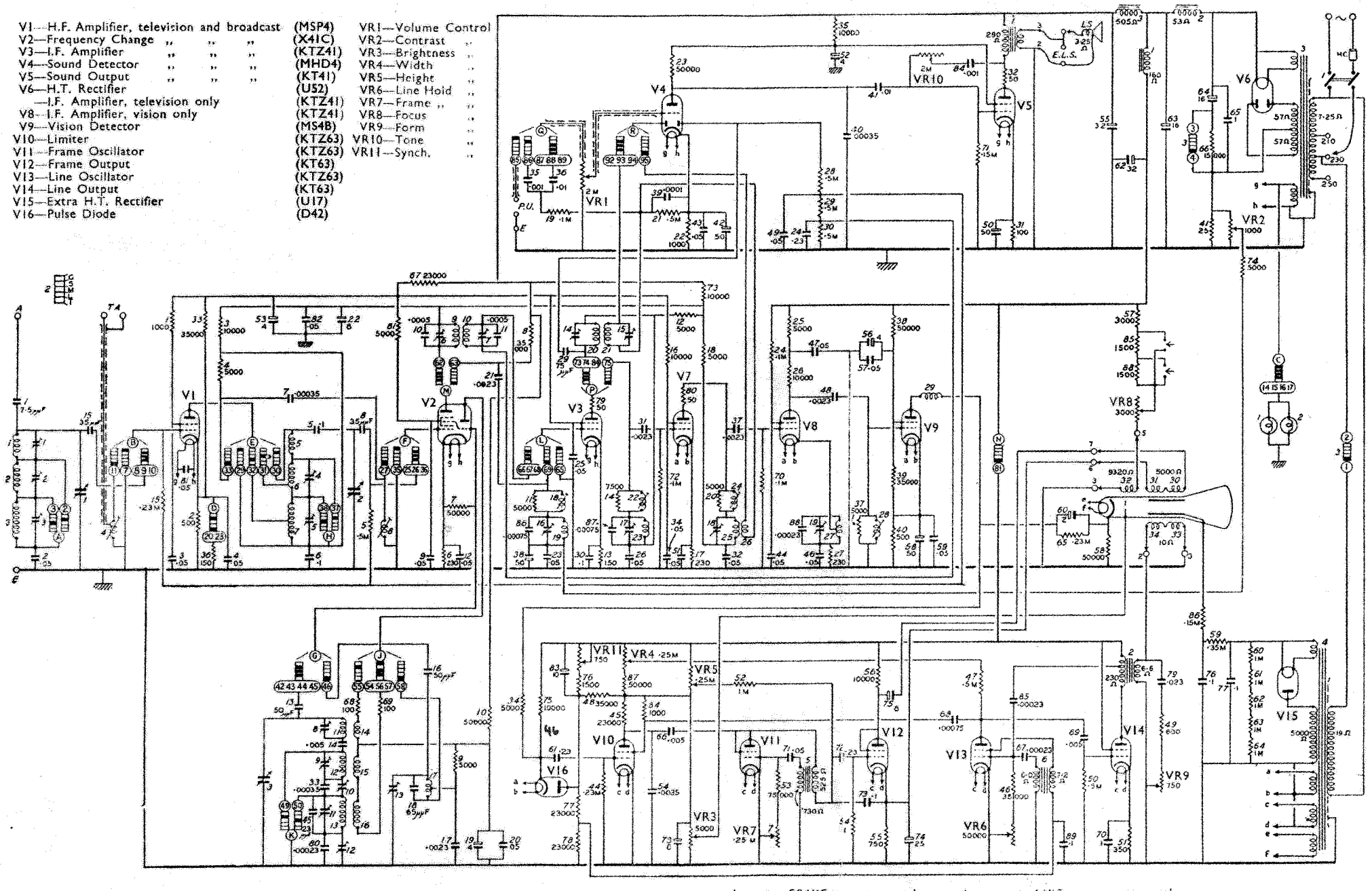
There was also moderate corrosion

The top of the HMV 904 chassis with the IF transformers still in place.



NOTE : To accommodate variations in the magnetic flux of the focus coil it may be necessary to vary the value of R57. Values of 2,500, 3,500, or 5,000 ohms (2 watt) may be used. Do not alter resistance until both positions of the focus adjustment have been tried. It is important that correct focus can be obtained in the first third of the rotation of the " Focus " control (from minimum).

V1—H.F. Amplifier, television and broadcast	(MSP4)	VR1—Volume Control	
V2—Frequency Change " " "	(X41C)	VR2—Contrast "	
V3—I.F. Amplifier " " "	(KTZ41)	VR3—Brightness "	
V4—Sound Detector " " "	(MHD4)	VR4—Width "	
V5—Sound Output " " "	(KT41)	VR5—Height "	
V6—H.T. Rectifier	(U52)	VR6—Line Hold "	
—I.F. Amplifier, television only	(KTZ41)	VR7—Frame " "	
V8—I.F. Amplifier, vision only	(KTZ41)	VR8—Focus "	
V9—Vision Detector	(MS4B)	VR9—Form "	
V10—Limiter	(KTZ63)	VR10—Tone "	
V11—Frame Oscillator	(KTZ63)	VR11—Synch. "	
V12—Frame Output	(KT63)		
V13—Line Oscillator	(KTZ63)		
V14—Line Output	(KT63)		
V15—Extra H.T. Rectifier	(U17)		
V16—Pulse Diode	(D42)		



NOTE : C14 may be made up of two condensers.

to it, resembling the original plating and has excellent longevity.

This can be further improved with a coat of clear lacquer, preferably VHT and oven baked. It was not practical to re-plate the many rusty screws so I obtained new ones of identical geometry and with the original BA threads, which were readily available.

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

The vernier dial was repaired by first scanning, 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.

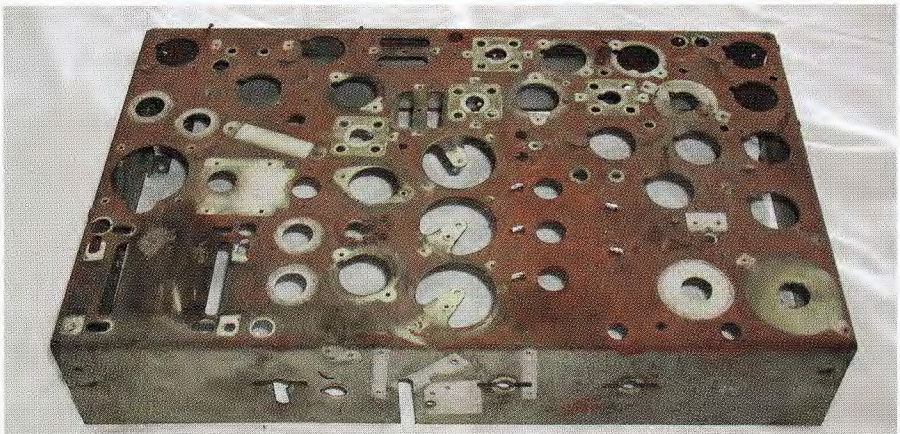
The electrolytic capacitors were replaced and the paper capacitors rebuilt with new caps placed inside and the ends sealed with polyester resin. The large EHT filter capacitor was also re-built. The original valve sockets were all replaced with high-quality vintage ceramic sockets, which after a lot of hunting, turned up in the UK.

Two of the dual-gang concentric 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.

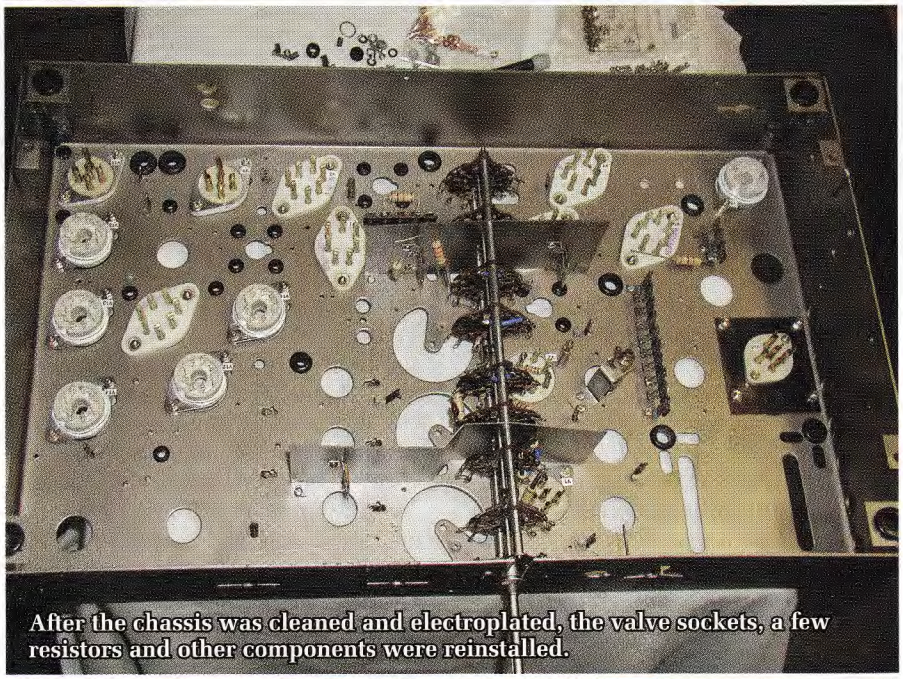
These were mounted to a flat PCB to keep them in an orderly configuration. The chokes, transformers and 3-gang tuning capacitor also needed to be restored.

Finally, the set was reassembled with the original under-chassis layout and original tag boards with the rebuilt 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. 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.

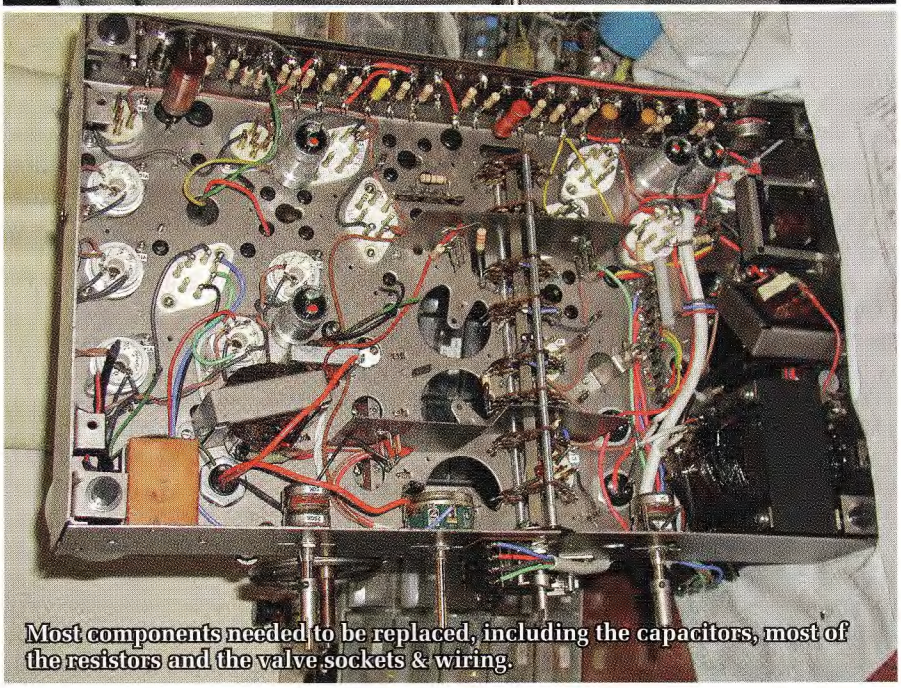
But many challenges still lay ahead, including the electrical alignment of



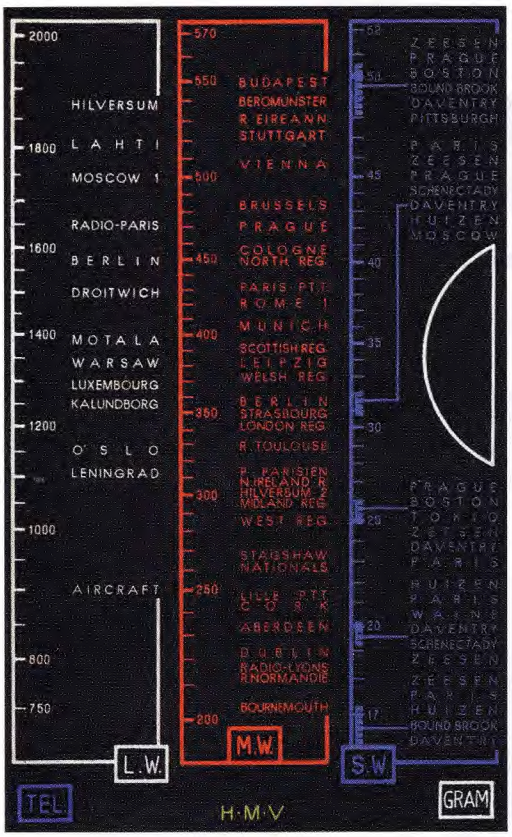
The naked chassis of the HMV 904 had rust over most places and some small burn marks.

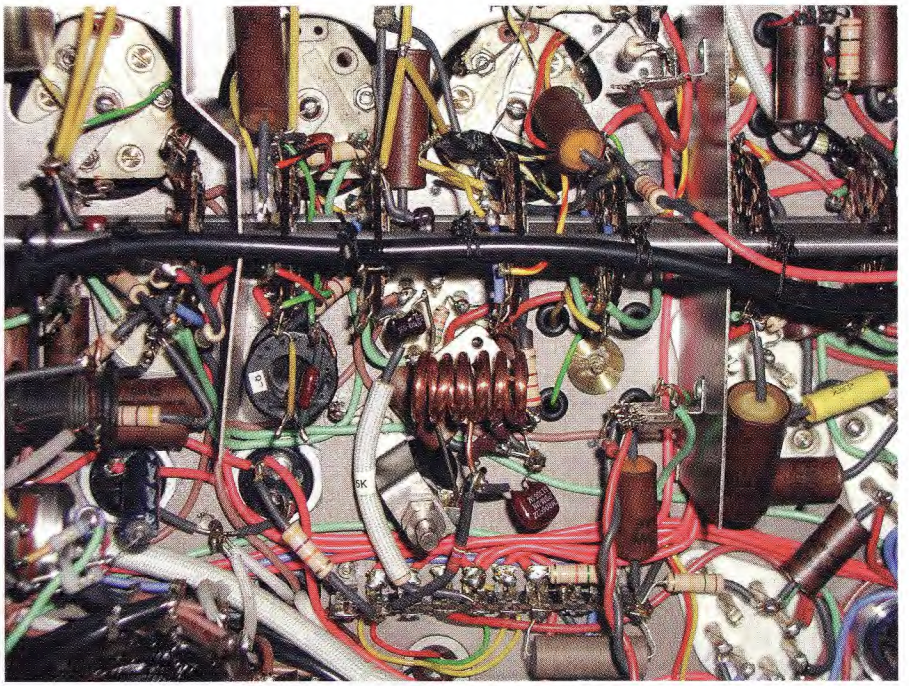


After the chassis was cleaned and electroplated, the valve sockets, a few resistors and other components were reinstalled.



Most components needed to be replaced, including the capacitors, most of the resistors and the valve sockets & wiring.





Left: the glass tuning dial only required a minor touch-up. The semicircular area is a window to the round white vernier disc seen on page 96. This disc is driven by a chain coupling to the variable capacitor's shaft.
Above: the copper coil is the tank oscillator coil for the X41C converter valve. Near it, some of the paper capacitors had their insides replaced with newer caps.

the set, what to do about the missing CRT and how to get a suitable 405-line video signal source modulated on to the correct carriers.

Vertical and horizontal output stages

The frame (vertical) deflection yoke in this set has a relatively large number of turns and a high DC resistance of 5kΩ. The output tube's (V12) anode load is a 10kΩ carbon power resistor (R56).

The yoke is coupled to the anode of V12 by an 8μF electrolytic capacitor, C75, and returned to the cathode of V12. So unlike modern magnetic deflection circuits, the load is predominantly resistive; not inductive and 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 a saw-tooth scanning current).

While the plate resistor they have used is very inefficient, it does provide a satisfactory degree of damping and doesn't occupy much space. As well, it is an inexpensive option compared to the usual frame (vertical) output transformer.

The line (horizontal) output stage is based on pentodes 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's iron core can just run satisfactorily at 10,125Hz.

If this line circuit is set to run faster, at 15,625Hz, 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 of around 11Ω 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 at the correct scanning frequency is quite acceptable.

A. D. Blumlein

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" in 1931. 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 during the post-war period, in an article by Otto. H. Schade (see references). This article references Blumlein's original patent for a non-linear deflection circuit with diode from 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 to be energy control/management systems. In deflecting a beam about centre, no overall energy is required, only enough to overcome losses.

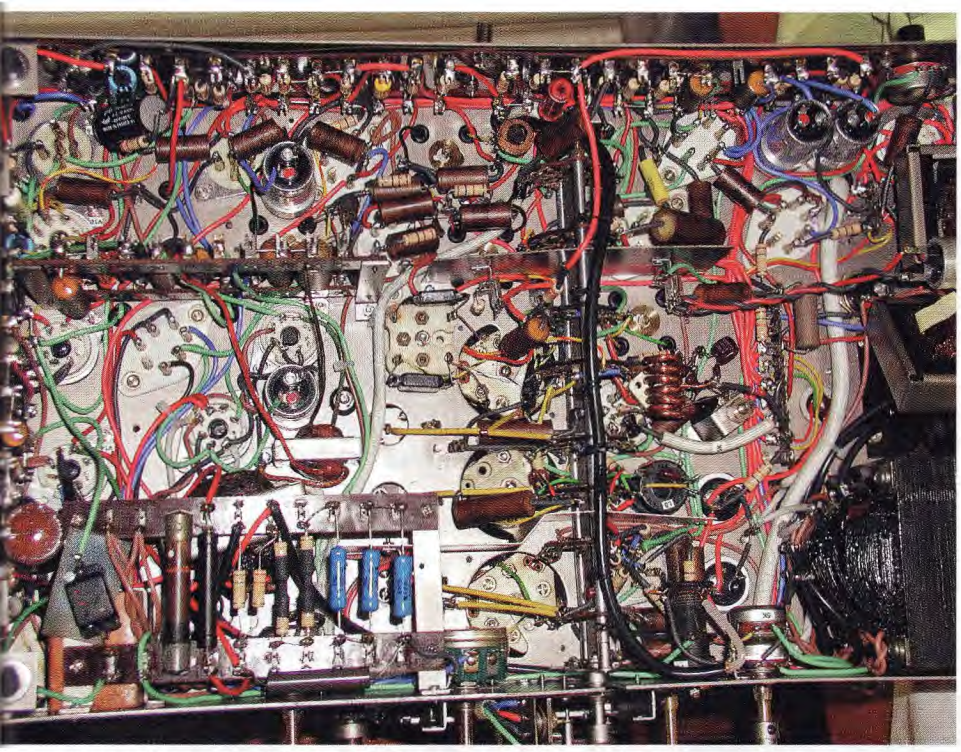
This is analogous to a swinging pendulum, requiring small amounts of additional energy per cycle to keep it going. Despite the early work by Blumlein in the UK, the damper diode concept had not found its way into the HMV 904.

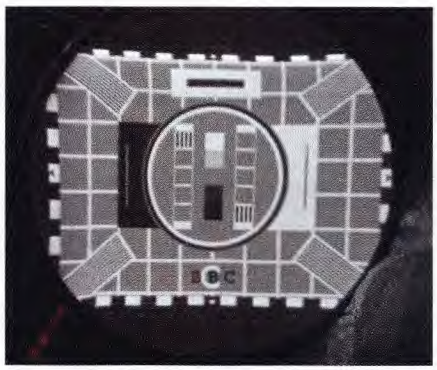
Anode bend detector

Being a combined TV/3-band radio, there are two AM demodulators, one for the radio and TV sound and one for the video detector, based on the MS4B (V9), a metallised glass tetrode.

This is biased as an "Anode Bend" power detector. This is the first time I have encountered this in a television set and is a very good idea. The anode is direct-coupled via inductor L29, capacitor C60 (2μF) and resistor R65 (230kΩ) to the CRT's cathode.

In effect, V9 is biased as a class AB amplifier. As a result, the "no signal"





Above: the underside of the chassis after all parts had been replaced.
Right: two shots from the 5FP4 tube; one of a test pattern from the 625-405 standards converter, and below it, a freeze frame from a PAL camcorder passed through the converter.

plate current is very low compared to its class A counterpart used in most television sets. This avoids power loss in the anode load resistor.

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 out 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, producing 25 to 30V peak-to-peak without any difficulties.

Electrical alignment

Following the manufacturer's 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 IF response of the set in the usual way, and much to my astonishment found that the intended video IF bandwidth was only 1.4MHz. 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 2.4MHz. 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 (see text below) is superior to both the electrostatically scanned 5BP4 and 5AP4 employed in USA prewar 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 readjustment with the front panel focus knob from time to time. I don't think constant current sources were on designers' minds back then.

Substitute picture tube

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 1950s and had no luck. Some were found later but with fairly low emission which would result in a washed out picture.

Steve McVoy of the Early Television Foundation suggested a 5FP4. This, like the 3/1, is a 5-inch magnetically deflected, magnetically focused tube that was designed post war by RCA for the viewfinder on the TK30 camera.

Significantly, this tube, as per the original is a non-aluminised tube, which is very important with the low EHT voltages. Aluminised CRTs require anode voltages between 5kV and 7kV.

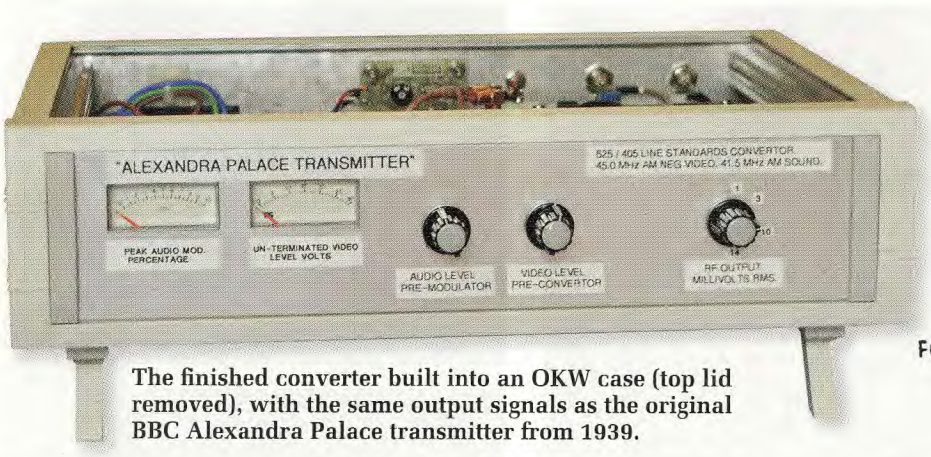
I located some 5FP4s and started testing. The neck on the 5FP4 is a little larger than the Emiscope 3/1, but removal of a small amount of cardboard from the centre of the yoke allowed it to just slip over the neck of a 5FP4. The 5FP4 tube specs suggest a minimum EHT voltage of 4kV but I had no difficulty running it on the 2.4kV in the HMV 904 set.

In the result, I found the 5FP4 makes an excellent substitute, as shown in the un-retouched screen shots of the set working.

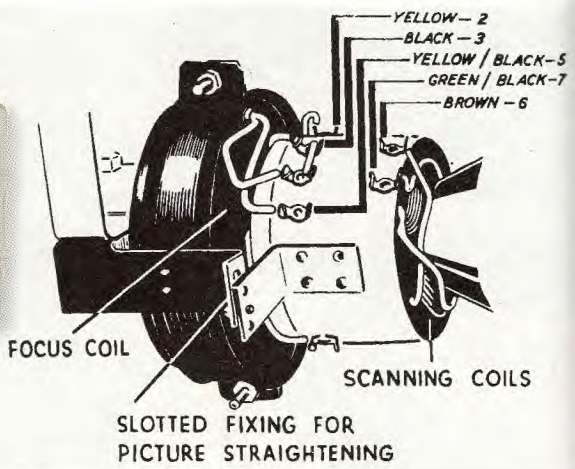
405-line video source and standards converter

All of the foregoing work would have been pointless without a source of 405-line video.

The test pattern originates from David Grant's converter board, and is shown on the previous page. The lower photo started out as a freeze



The finished converter built into an OKW case (top lid removed), with the same output signals as the original BBC Alexandra Palace transmitter from 1939.



frame image from a PAL camcorder and was passed through a 625 to 405 video standards converter.

Vintage television collecting is becoming quite popular in the UK and a few talented people have turned their hands to making standards converters. These receive a 625-line video source, basically digitize it, store it in memory and then read it out at the lower 10,125Hz line rate.

I acquired a standards converter as a set of two boards and small motherboard from David Grant in the UK. This converter also has an onboard 405-line 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 BBC Alexandra Palace transmitter in London. The unit can provide an RF output of up to 14mV RMS into 75Ω, but in practice 3mV is a suitable level for the HMV 904.

Conclusion

The overall performance of the 904 is very good. The radio section gives excellent performance and the CRT image is quite acceptable, despite the relatively low video bandwidth of 2.4MHz.

This is primarily because the lower resolution is simply not as noticeable on a 5-inch CRT. The benefit of magnetic focus is obvious, so despite the poorer IF bandwidth compared to the US-designed 5-inch Andrea and Meissner 1939 TV sets, the overall picture is comparable over a range of contrast settings on the three sets I have.

The sound on the 904 is very impressive. These pre-war TV sets have a relatively wide bandwidth in the sound channel compared to standard AM transmissions on medium or short-wave.

To me, the audio quality is indistinguishable from the FM sound in modern PAL sets. The effect is enhanced by the usual Class-A audio output stage and good-sized timber cabinet with a permanent magnet 6-inch speaker.

The fully restored unit with replacement tube.

At right is the scanning coil assembly of the yoke, while the diagram on the left shows the full yoke with the focus coil and scanning coils.

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 CRTs with their more elaborate gun structures probably cost more than the Emiscope 3/1 or the 5FP4 to produce, but likely not by a great deal.

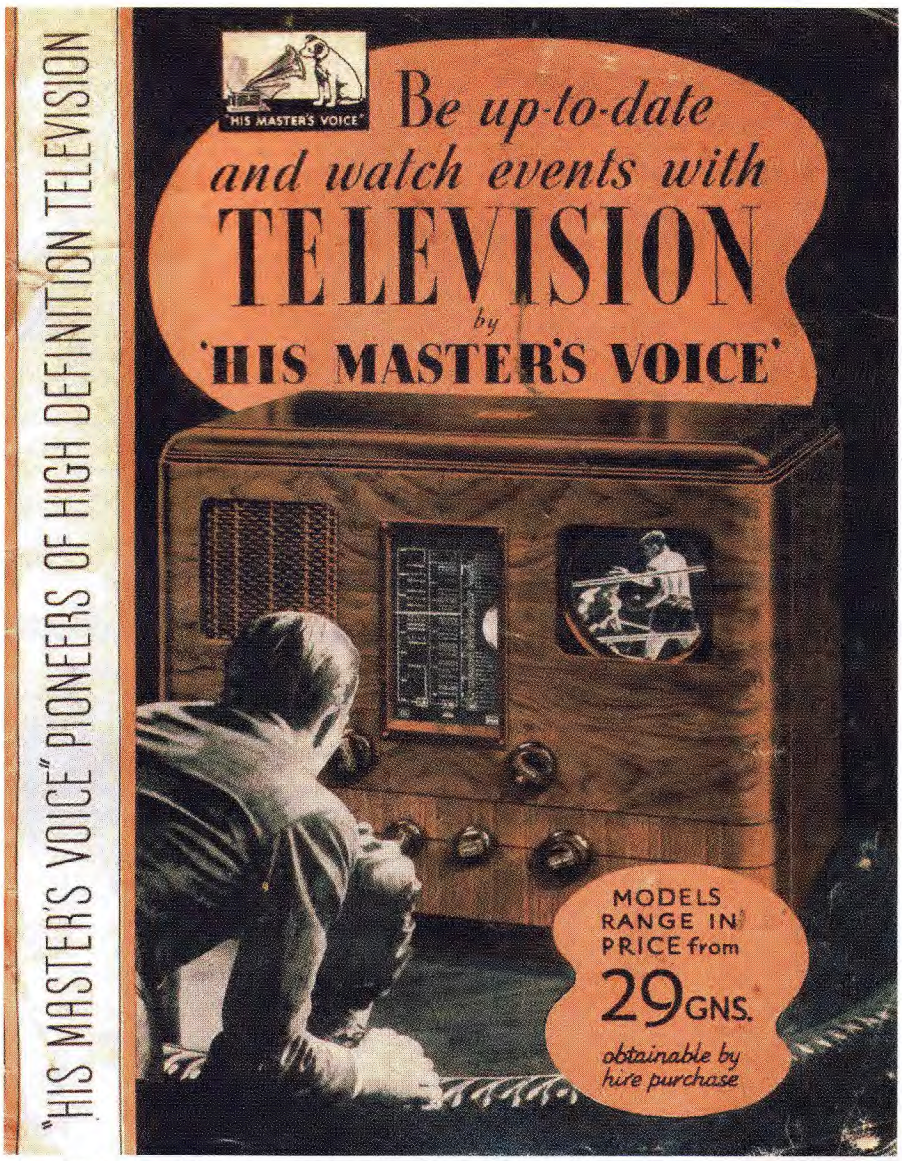
Ultimately, magnetic deflection won out over electrostatic, because larger electrostatic CRTs required very high deflection voltages. With electrostatic deflection, for any deflection voltage, the amount of beam deflection obtained is inversely proportional to the EHT voltage.

In magnetic deflection, for any deflection current, the amount of deflection is inversely proportional to the square root of the EHT voltage. Higher EHT voltages are required for bright high contrast images on larger CRTs and magnetic deflection is more practical for that reason.

Finally, one cannot fail to be impressed by the level that television technology had reached by 1939. Viewing programs on these sets is not a great deal different from observing them on any black and white television manufactured decades later, in the 1950s and 1960s.

In my opinion, the 904 was very advanced for 1939, with its magnetic deflection, magnetic focus and multi-band radio, all amazingly compact for that year.

The Aurora 625:405 line converter is popular in the UK and is used by most TV restorers (David Grant's converter is harder to get).



The "high-definition" HMV 904 cost 29 guineas back in 1939, which would have been very expensive to purchase at the time.

Tips for restoring pitch-coated transformers

The pitch coating on transformers hardens and cracks as it ages. In the case of line output transformers, this can lead to corona discharges and insulation failure. Laminated iron core types often also have a rusty stack.

One way to deal with this is to place the transformer in a bath of mineral turpentine. Over a few days, the pitch dissolves. An occasional gentle stroke from an artists' brush will help this process along.

In the case of a line output transformer, it should then be dried and dipped multiple times in marine spar varnish to build up a thick coat.

In the case of a rusted iron core type, such as a mains transformer or choke, after the pitch has been dissolved, the visible lamination rust can be cleaned off with 800-grit sandpaper.

The stack should then be painted with Fertan (organic rust converter) which leaves a dark blue-black finish on the lamination surfaces, prior to the varnish dip. When the varnish dries it leaves a non-sticky surface and does not attach to dust particles, unlike the pitch.

References

❑ 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.

❑ Basic Television, Second Edition, Grob. McGraw-Hill Book Company, INC. NY, 1954. pg 48.

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