The Care and Feeding of Vintage Broadcast Cameras

Restoring an old broadcast television camera to working order is not something to be undertaken lightly, it is not that it is very difficult, more that there is a lot of it! If you are fortunate enough to be contemplating an old camera channel, read on. If not many of the comments and techniques are applicable to other restoration items, even radios! This article is illustrated by a recently restored Marconi MkIII and many of the comments relate to the work done on it.

Figure 1. The Marconi MkIII camera

Where to start?

I know it is a statement of the obvious, but you need to make sure you have all of it! Or at least enough to make a start. In general terms a camera channel comprises: -

- A lens, zoom or fixed focal length. Fixed lenses go on a turret with 4 spaces (usually). Zooms have controls or servo demand units. Lenses should have rayshield hoods.
- The Camera with its viewfinder, monocular or large, and viewfinder hood. Make sure the camera has all its internal plug in cards and modules, and that they are for the line (and colour) standard you want.
- The CCU. Broadcast Cameras, except for the most recent models, connect to a CCU. Therefore, you will need the CCU and some cable of the correct type to connect them together. Multicore camera cable, with its co-ax cores, screened quads and single wires, is made to suit a particular camera or small range of cameras. Later cameras used the Triax cable, which is still in use today, so it is hard or expensive to get!
- Very early cameras had a separate PSU which connected to the CCU with more cable. This is a standard multicore cable, but the connectors can be a challenge. Later models had the PSU in the same box as the CCU. If the PSU is of the switch mode type, they can be a challenge to fix.
- The earliest cameras had the operators controls on the front of the CCU with only the most rudimentary provision for remote control. Then cameras had remote panel for operation of the controls wired back to the CCU. With the arrival of the microprocessor, the OCP and RCP became simpler and a MSU dealt with the now vast range of adjustments for a single or group of cameras. The MSU is often missing and setup of a modern camera is difficult without it.
- That is the basic camera channel, but there may be auxiliary units needed. If the camera is older than about 1975 it is likely to need “drive pulses [i]” from an SPG. Most important is the documentation. You will need the full handbooks or at the very least a full set of circuit diagrams and component layouts.

Figure 2. MkIII camera cable connector from 1953

Safety Notice

You should be aware that all tube type cameras have an interesting selection of high voltages in them, even the transistorised cameras have voltages of the order of **700 volts in them! This can give you a nasty nip, possibly fatal! If you are not trained in safe working practices, you should NOT be working on this type of equipment.** Also note that the wiring practices of the 1950’s are a long way short of today’s standards. The use of a mains isolating transformer in addition to the Variac is recommended.
You should not work alone!

Cleaning

I give a fairly good clean before I start, using a paintbrush in conjunction with an airline blower to get the worst of the dirt and spiders out! Some things can then be washed, even components with a degree of care and then blown out again with the airline. Some cameras (Pye & Marconi) have nice little labels on the individual parts (R35 C129 etc) and care has to be taken with these labels as they come off very easily. I leave the paint touching up until later. There will be a lot of time to do this when various bits are being soak tested. The complexity of the chassis and wiring mean that it is not practical to strip units down for repainting or plating, as is often done with vintage radios. It is my view that this destroys the originality of the item under restoration. It is restoration not rebuilding.

Preservation

I like to think I am saving these cameras for the future, so my approach is to replace as little as possible. Think of the "this is my great grandfathers axe, it's only had 2 new heads and 4 handles" syndrome. The other thing that really concerns me is keeping a channel complete. I have seen many instances were only the "photogenic" camera head is saved, the inconvenient CCU and PSU being lost for the future. To this end, I have been collecting complete cameras channels for my museum.

Components problems

- People worry about valves but provided they have a good vacuum and light up they are probably going to work. Be careful when inserting and removing valves from their sockets, particularly with octal[ii] valves as the centre spigot can break off. If the pins are corroded you can clean them with a fibreglass brush (available from Farnell etc.) The valve sockets are normally OK as they would have been good quality ones and they last well. Gently rotate an old faulty valve in the socket, with a few drops of contact cleaner to clean the socket. Take care with Top Cap connections. It is annoyingly easy to break the cement holding it on. For B7G and B9A glass valves there is sometimes a metal pin straightening socket.
- Transistors do age slowly and can give an interesting range of cracks, pops, hisses and leakage. If the camera has been in a damp area, the transistor connections (legs) can go rusty and the transistor falls off. The wires are often plated steel, try a magnet! When sourcing replacements, if the correct type can't be found, a substitute with suitable ratings will often work satisfactorily.
- Tubes (pickup) Try to make sure you get the correct tubes with your camera. Spare tubes are about and can be found with some effort. Strangely, the later small size Plumbicons[iii] seem to be the hardest to find. Always keep the target (faceplate) uppermost when handling. Tubes do wear out, losing performance, with loss of emission and target deterioration. They rarely stop working completely and it is good to have some poor tubes for testing with as you can damage good tubes in a faulty camera.

Figure 3. Faulty components removed

- Resistors go high in value, especially the green vitreous power kind. These go open circuit, and it seems to be a feature after 40 odd years, check them all! Small resistors of the carbon composition type also go high, but not all will need changing. The original types may be of 10% or 20% tolerance and the circuit may well work satisfactorily if the value has not changed too much. Variable resistors go intermittent and noisy. Try cleaning first and rotating a lot. With use they often improve to a usable state. It is difficult to find suitable replacements.
- Depending on the age of the camera there may be a number of TCC brown, oil filled paper capacitors with voltage ratings of 2,000 to 20,000volts. I have had trouble with these. Even apparently good ones have failed after some use. They get hot and leak nasty oil even splitting open in some cases. It is problematic to find suitable reliable replacements that look the part. I cannot recommend using the hollowing out tequnique sometimes advocated, as the oil is nasty stuff. The best bet is to make up a brown tube and fit a stud bolt to either end with filler compound (brown window sealer, the non acetic

acid sort). I didn't have time or patience for this and just wired new capacitors in on tags for later attention.

- Capacitors give endless problems, some makes more so than others. If you have any of the "Hunts" type, brown or black with thick plastic coating, best replace them all. I am deeply suspicious when I see them. Sometimes the plastic has cracked and shrunk back exposing the innards! If your camera has Tantalum[iv] capacitors, red or blue bead type (1970ish), they will give trouble if they have not had voltage on them for a while. Paper capacitors go leaky and a judgement has to be made about which you replace. The leakage has more effect in certain grid circuits than in others parts of the circuit, where a small amount of leakage is of no consequence.
- It is not unknown for capacitors to explode (burst open). Watch out for increasing leakage that leads to overheating and internal pressure. This is more likely to happen with electrolytic capacitors. They can make a dreadful mess, tinfoil and goo everywhere.
- Transformers for broadcast cameras are well built and give little trouble with the exception of some in Pye cameras from the 1960s. Make sure you do not destroy a transformer by failure of another component leading to excessive current demand, overheating and failure. It will be difficult to replace a failed transformer as they were usually especially made to fit. Check carefully that all fuses are of the correct value and surge[v] rating.

The PSU

I like to start with the PSU, it is often big and has lots of nasty high voltages but fairly easy to get going. These notes relate to valve type equipment, but have relevance to later solid state equipment.

- Check for mechanical damage, broken wires, resistors, valves (valves go white if the air gets in). Remove all valves and put to one side for later reinsertion. If the numbers have been rubbed off write the number on the base with felt tip. Check the mains input voltage selector is correctly set! Check carefully that all fuses are of the correct value and surge rating.
- Re-form[vi] the electrolitcs. Use an external variable HT power supply with a current limiting resistor(s) and a current meter. Connect to each capacitor in turn and start with a lowish voltage say 100 and watch the series current meter, which should fall to a low value. When it has settled increase the voltage and wait until it settles again. Repeat this until you have reached the working voltage of the capacitor. A certain amount of experience is needed to judge when electrolytic capacitors are satisfactory. A leakage of about 1mA. or less would mostly be acceptable. Watch out for parallel current paths which will make the leakage appear more than it really is. It is possible with some thought to do the re-forming without any disconnections. This is a good plan as the PSU, this article is based on, has 15 major electrolytics alone! At no time should the case of an electrolytic or any other capacitor get warm!

Figure 4. The PSU before restoration started

- When you are happy with the electrolytics and have oiled the fan, checked the insulation of the mains input circuits and check that there are no short circuits cross the HT lines. You can apply some power. Use a Variac[vii] to bring the voltage up slowly and check the secondary voltages on the mains transformer(s). It maybe that you will have to link two of the pins on the output connector as there is often an interlock to stop the PSU working if not connected to the CCU. If nothing has gone bang, plug the valves in and connect a dummy load to the output. This is important, as without a load the output voltage will go too high. I used a domestic 150w light bulb, it worked well and you could tell when the PSU was on! Check the regulation[viii] of the output voltages with different amounts of load. They should not change by more that a few percent (1% to 5% typical range). Set the output voltage, I like to set it a bit low, perhaps 20 volts (for nominal 250v) low as it can be increased later.
- Most early PSU had meters for measuring the output currents and voltages. A very careful watch of the output current should be kept. It is likely that the current will rise as the camera warms up and the leakage of capacitors increases. If it goes up much or quickly switch off and investigate!!

The CCU

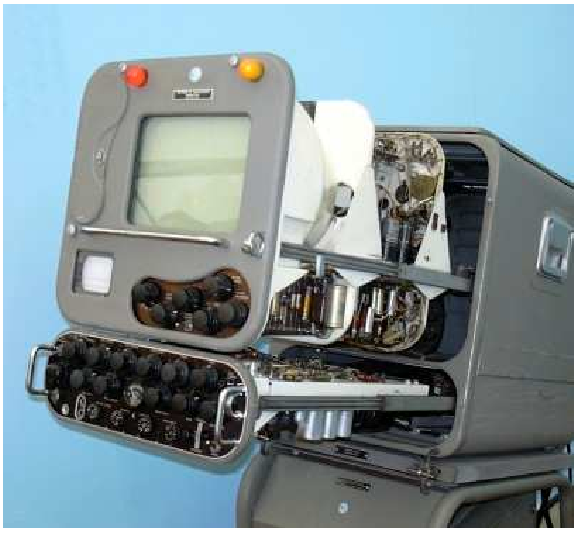

Figure 5. The CCU with it's picture and

- Much of what has been said about the PSU applies here. Remove the valves and re-form all the electrolytics, check resistors, small capacitors and look for wires off and damage. It is likely that the CCU has it's own transformer for the 6.3volt heater supply, so if you connect the PSU to the CCU and remove the HT rectifiers you can plug the valves back in and power up with no HT from the PSU. Use the variable HT, supply used for re-forming the electrolitcs, to bring the voltage up slowly, looking for smoke as you go. It is a little known fact that most electronics works by smoke and if it escapes it stops working! Oh-Hum.
- If your camera is a later solid state model you can do a variant on the above by plugging in the PCB cards one at a time watching for smoke. Remember the Tantalums! Make sure that you load the PSU suitably at all times so it is not upset by too little or too much load.
- It's about now that you can connect the SPG feeds and see if there is an output? Some CCUs have to be fooled into thinking there is a camera connected. You could connect the camera at this stage in a minimalist way with most boards/units removed. Most CCUs have some arrangement for generating a local test signal and there is no point in working on the camera until the CCU is producing a correct output.
- The video amplifier in the CCU processes the signal from the camera head, adding blanking[ix], clamping[x], lift[xi], control of the gain, white clipping, and finally sync pulses are added. All these processes will have to work. See suggested reading list.
- Later cameras like the Marconi Mk8/9, the Phillips LDK5 and some Link cameras are a bit all or nothing as regards getting the PSU/CCU/camera to work independently. You have to tread carefully.

The Camera Head

- As before inspect for mechanical damage, re-form electrolytics, etc. disconnect the viewfinder and lens for later attention. Remove the camera tube(s) noting carefully the orientation in the scanning yoke[xii] . In a 3 or 4 tube colour camera you could consider just disconnecting the tubes, leaving them in place. This will make later registration[xiii] easier. Do not fiddle with the mechanical adjustment of the yokes for the same reason.
- Image Orthicon cameras have +1400volts for the electron multiplier and –600volts around the Image section, mind your fingers! Plumbicon and vidicon cameras have 900 to 600volts on the wall anode. These voltages can come from the PSU or they can be locally generated in the camera.
- Connect the camera to the CCU and having removed as much of the electronics as practical, bring the voltages up slowly watching for signs of distress or overheating. Plug the modules back in, checking things as you go.
- If the camera has it's own PSU get this working now. Middle period cameras, 1965 to 1980, often sent a single high power supply to the camera which was converted to the range of voltages needed in the camera.
- It will be possible to inject a test signal into the camera at the start of the video amplifier and you should get this working first, through the camera and CCU to the output.
- Then move on to the scanning sections, high voltage generators, scan failure protection circuits and focus supplies. Check the voltages at the tube base connections and also that the scanning generators are actually working before inserting or connecting the camera tubes.
- During all the work in progress keep an eye on the total current drawn by the camera channel. It is hard to get it down to the value stated in the specifications. How near you get to this is a measure of all the small leakages and extra valve current due to incorrect operating point caused by capacitor leakage or changed value resistors. A result of the extra current drawn is extra heat, leading to more leakage…

Viewfinder

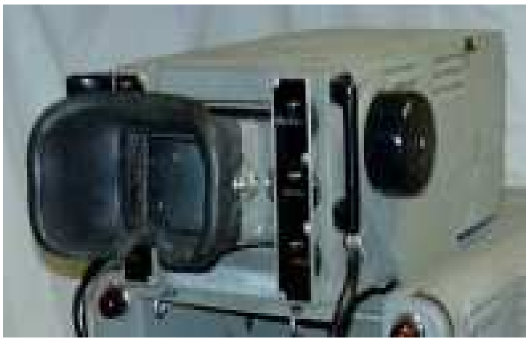

Figure 6. The Marconi MkIII Viewfinder

- The viewfinder is basically a small good quality picture monitor. Therefore normal monitor or TV servicing practice applies. Depending on the designers preferences and sometime the budget, the viewfinder can be more or less "stand alone" or it could be more integrated with the camera needing drive pulses and voltages from the camera. Cue lights and lens indicators are often integrated into the viewfinder. Late cameras could put text messages on to the viewfinder.
- There is a problem with viewfinders from about 1970. A faulty batch of 7 inch tubes with bonded on flat glass faceplates were manufactured. The trouble did not become apparent for 2 decades, but the "gel" material between the tube and the faceplate goes very spotty and strange. You will know it when you see it. Later tubes of the same type are unaffected.

Optical systems

- The lens focuses the image of the scene onto the target of the pickup tube(s). On its way, it has to be controlled in intensity and colour temperature. All broadcast cameras will have a means of controlling the tubes exposure, normally a servomotor driven iris.[xiv] In addition to the iris there will be a number of neutral density filters mounted in a rotating disk. This can be motor driven and controlled from the CCU. In colour cameras, a second ring contains coloured filters, minus blue or star filters. Turret cameras have 3 to 6 places for mounting lenses and when fitting them the iris gear ring arrangement should be moved, so that all the lenses are set to the same aperture, say f8, so that the lenses track. The Zoom lens will have controls for zoom and focus with local servo or mechanical operation, the iris control being remotely controlled. In some cameras provision was made for local iris control.
- The optical path should be cleaned with care using a lint free cloth. Great care should be taken with mirrors and prismatic light splitters. It may be better not to clean! Filters, lenses and tube faceplates are more robust. Clean with care.

Operation and Alignment

- At this point, the camera channel should be fault free, or nearly so. The scanning and video circuits must be working, as you will not get a picture if they are not satisfactory. Cap the Lens[xv], insert and connect the tube(s). Do not adjust any of the pre-set controls in the camera or CCU as they are likely to be set to the correct value, or nearly so.
- Turn the Beam control(s) to zero and set other front panel controls to the centre or as dictated in the setting up instructions in the documentation.
- All tubes, Vidicon, Plumbicon, Image Orthicons have a beam of electrons that scan over the tube's target. Many of the adjustments are to do with controlling this process. The beam must have the correct current, be aligned, focused, and deflected to scan the correct target area and arrive at the target with the correct velocity. In addition, the Image Orthicon tube has an image section in front of the target with more controls.
- There can be as many as 4 separate focus adjustments, optical, image (Image Orthicons only), beam electrostatic and beam magnetic. Most tubes need an overall magnetic field, generated by a solenoid coil in the yoke with a stabilised current flowing in it and an adjustable voltage on the tube's focus electrode. There can be more than one focus node of the electron beam within the tube, one of them will give the best performance.
- When the camera has warmed up, say 5 minutes, and the test signal from the camera is Ok turn off the test signal, un-cap the camera and advance the beam control. If you are really lucky, a picture will appear, more likely not. As you advance the beam control, watch the output picture for a change in brightness or noise level. This is the start of the beam landing on the target. Don't use too much beam. It has to be enough, but too much will lead to poor results or even none. The correct point is to just "discharge the whites" in the picture.

- If you have a colour camera from about 1975 onwards, it may have dynamic beam control to deal with light overloads which caused coloured trails to follow bright objects (comet tails). This was variously called ACT or HOP. The adjustment of these circuits must be correct or tube damage may result.
- Make sure there is an optical image on the face of the tube and adjust the alignment and beam controls. When some sort of an image appears you can start the optimisation process. Image Orthicons have the image section to adjust as well. If there are no faults, maladjustment of the alignment and beam controls are the main reason for there being no picture.
- A full line up of a camera can take a long time, a lot of experience and the manufactures set-up instructions should be followed. Colour cameras are much more complex as the coloured images have to match in amplitude, position and size. It helps a lot if you have not disturbed the optical positions of the 3 or 4 scanning yokes and tubes.
- There is an alignment technique variously called minus Green (-G). This is used in the alignment of the image registration. The green signal is inverted and added to either the red or the blue signal. Where the pictures are in registration the signals will cancel to grey, the errors showing as bright edges. This is best displayed on a good underscanning[xvi] monochrome monitor

Test Gear

- You will need the usual set of servicing tools, testmeters, one digital and one analogue, an oscilloscope with at least 20MHz bandwidth.
- A Megger with 250v & 500v operation for measuring capacitor leakage.
- HT power supply, adjustable from 100v to 450v at, at least 100mA. LT power supply 0 to 50 volts 2A.
- An LCR bridge.
- A good monochrome picture monitor and a colour monitor as well if you have a colour camera.
- A TV waveform monitor[xvii] and a vectorscope[xviii], TV test signal generator, an SPG.
- A selection of test cards and an illuminated stand for them.

Suggested reading list

Practical Television Engineering,	by Scott Helt,	Pub. Rinehart Books	1950
Television Engineering,	by Amos and Birkinshaw, Vols. 1 to 4,	Pub. Iliffe,	1953*
Basic Television,	by Bernard Grob,	Pub. McGraw-Hill	1954
Television Engineering Handbook,	by Donald Fink,	Pub. McGraw-Hill	1957
Sound and TV Broadcasting	by K R Sturley	Pub. Iliffe	1961*
Principals of PAL Colour Television	by H V Simms	Pub. Iliffe	1969*
Television measurement techniques	by L E Weaver	Pub. Peter Peregrinus Ltd	1971*
Video Handbook, second edition	by Ru Van Wezel	Pub. Heinemann: London	1987

All of the above are heavy-duty technical handbooks, even the early valve ones have principals still in use today. * These books have been published in conjunction with the BBC and issued as training books.

Notes

Experts and purists should note that there are many simplifications in the foregoing texts.

Marconi MkIII brief data

Valves: 91 valves in total plus 3 CRTs and the camera tube.
Weight: 170LBS (77Kgs.) camera only.
Power: 1000watts approximately
Models were available for 405 lines, 525/60 lines and 625/50 lines and with 3” or 4.5” tubes.
303 were made, 181 for the UK and the rest for export.
Camera Power Supply is the main power supply for the whole camera chain. It had a regulated output of 250volts DC at 1.25A. and 330volts at 330mA. Additionally there were some miscellaneous outputs at lower voltages. It used 17 valves for rectification and stabilisation. It came in two forms, rack mounting or in the mobile case form. In order to keep the weight down, in the mobile form, a forced air-cooled mains transformer was used.

For more information on the Marconi Mk III go to:- http://www.bsvideo.dsl.pipex.com/marconimk3doc.pdf

Glossary

ACT	Anti Comet Tail
CCU	Camera Control Unit
CRT	Cathode Ray Tube
BG	Burst Gate
FD	Field Drive
HOP	Highlight Overload Protection
HT	High Tension (voltage)
LD	Line Drive
LT	Low Tension. In valve parlance less than say, 10V or less than 100V in solid state areas.
MB	Mixed Blanking
MS	Mixed Syncs
MSU	Master Setup Unit. Complex controls for a group of cameras.
NTSC	National Television Standards Committee, The American (60Hz. Areas) colour system.
OCP	Operational Control Panel
PS	Pal Squarewave, also called VAS in BBC areas Vertical Axis Switch
RCP	Remote Control Panel, normally a less complex version of the OCP
SECAM	The French colour system.
SUB	Subcarrier (sinewave signal 1 volt PPk.)
SPG	Sync Pulse Generator
Triax	A coaxial cable with an extra overall insulated screen.
PAL	Phase Alternate Line, the European (mostly) colour system
PSU	Power Supply Unit
VAS	in BBC areas Vertical Axis Switch also called pal switch in other areas

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[i] **Drive pulses:** (or just pulses) refers to the output pulses from a central SPG used to control the timing of a group of cameras. Most cameras used a subset of the full set of seven pulses, depending on the age and type. (LD FD MB MS BG PS SUB)

[ii] **Octal:** In this usage a valve with an 8 pin Bakelite base, glass or metal body.

[iii] **Plumbicon:** A lead Oxide based camera tube made by Philips Trademark.

[iv] On this point if you have a “working” camera with these red or blue Tantalum caps in it, it is a good idea to power it up every few months to stop them going bang! Very tedious as it is likely to have dozens or even hundreds of them.

[v] **Surge:** In this context fuses can be “quick blow” or “slow blow” surge resistant types.

[vi] **Re-forming** electrolytic capacitors, is a process of restoring the insulating layer to its original value by applying a voltage which is slowly increased.

[vii] **Variac:** A variable voltage auto transformer. Note that it is not an isolating transformer. The voltage is adjustable from 0 to 260volts. It should have a current rating of at least 2 amps, ideally 5 amps.

[viii] **Regulation:** Refers to how well a stabilised power supply controls its output voltage.

[ix] **Blanking:** The raw picture from the camera is oversize and the edges are often poor, so these are blanked off to give nice crisp edges and a picture of the correct size.

[x] **Clamping:** A process of picture stabilisation to give a defined black level.

[xi] **Lift:** The adjustment of the black level in the picture.

[xii] **Scanning Yoke:** In a broadcast camera this is a precision wound set of coils to do the horizontal and vertical deflection of the electron beam. There will be coils for adjusting the beam alignment, and overall beam focus.

[xiii] **Registration:** The adjustments needed to make the scanned patch in each of the colour cameras tube match so that the coloured images are in alignment.

[xiv] **Iris:** An arrangement of moving vanes to present a circular aperture on variable size in the light path of a lens

[xv] **Lens Cap:** An optical blanking arrangement to stop light reaching the tube(s). It is literally a cap on the end of the lens, but sometimes there is a blank position on the filter wheel or the lens iris can fully close.

[xvi] **Underscanning:** On a picture monitor tube the amplitude of the scanning is reduced to show the edges of the raster. Engineering picture monitors are normally operated in this mode. There should be a switch for it.

[xvii] **Waveform monitor:** A specialised oscilloscope for displaying television waveforms.

[xviii] **Vectorscope:** A specialised oscilloscope to show the amplitude and phase of the colour subcarrior in a coded PAL or NTSC signal.