DRAFT

Crosley Radio Project

John B. Gilmer Jr.   August 2, 2025

Background:

I am in receipt of several early Crosley radios from circa 1924 that are in various conditions of disrepair. These were received from Mr. Robert Taylor, former Chair of the Department of Electrical Engineering and Physics at Wilkes University. His father had worked on these radios as a hobby, and these remained in the condition found. I had recently done a presentation for the Wilkes IEEE Club on early radios. These Crosley radios, brought in by Mr. Taylor, were in fact earlier than any I had available for exhibit and demonstration, the earliest being a 1927 RCA Radiola 17 from my grandfather's time. I accepted these Crosley radios in the expectation of getting at least one working for a future demonstration. They are unique in having regenerative detectors, which is an interesting technique not found in more recent radios, although a single tube electronics kit I had as a child did feature such a regenerative radio among its projects. So, my intent is to get one or more of these radios working and functional. This paper in draft form is written "as I get to it." It includes some blind alleys and errors on the way.

The radios:

There are five radios, all of which are similar in the principle of operation, having a single regenerative detector, and usually one or two audio amplification stages. All were designed to work from batteries. The radios are of three different models:

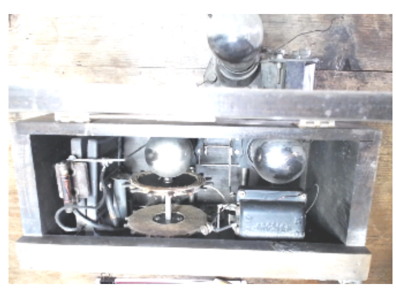
1. **Ace Type V** (serial number 9492): This is a single tube radio with just the detector stage. The binding post for the antenna (upper left corner of the faceplate, marked "A," is missing. So is the binding post for the "B+" connection, in the upper right corner. The "Output" connector is loose, and the bus bar inside the radio from this terminal is loose. The controls (Capacitor, tuning selector, rheostat, and regeneration) all seem to all be functional. The vacuum tube is missing. There are no obvious other problems, but this is merely a superficial visual inspection. (It is possible that the missing terminals were used to repair other radios.)

2. **Crosley 51**: This is a two tube radio, with an initial detector stage similar to the radio above, followed by a transformer coupled single stage amplifier. The cardboard identifying square giving a serial number is missing. This particular radio is unique among the five in having a socket for a small incandescent light bulb in the upper middle of the front panel, mid-way between the A and B+ terminals. Nearby and to the right is what seems to be a sealed hole in the front panel labeled "B22+" where, presumably, a terminal once was. Was this a factory modification or adaptation, or a user improvisation? I don't know. The four controls, with the same functions as those of the Ace V, all seem mechanically functional. Inside, there are no

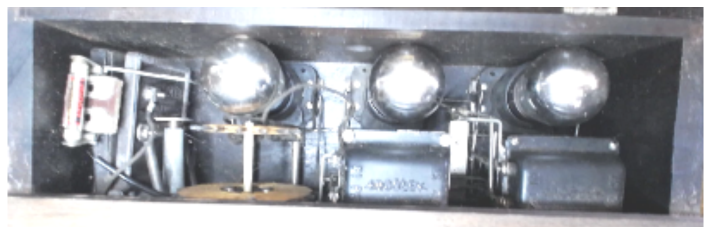
loose wires except a cord with four conductors (red, white, yellow and black) led out of the radio through a hole of ½ inch diameter in the back panel. The hole looks like it may have been original. These wires presumably connect to the A and the B batteries. The two tubes could not easily be extracted from their sockets, and have been left in place for now. (Determining which tubes are present is important, since the type 51 can be used with tubes of varying filament Voltages. Thus, the radio needs correspondingly different A battery power sources ranging from 1 ½ up to 6 Volts, and possibly B+ variations.) Nothing seems to be visibly missing.

3. **Crosley 51** (serial number 148487 E): This radio is similar to that above, but there are some very distinct differences. Most obviously, the front panel is wooden rather than made of Bakelite or some similar hard substance. There is no socket for a light bulb. There is merely a hole where the label identifies the "B22+" terminal, with some scoring that indicates that this terminal was once there. All that is left of the antenna terminal is the screw sticking out of the front panel. The same is true of the output terminal and another unlabeled terminal under it. The holes are there and a screw sticking out, with the case finish darker out to a circle indicating that these terminals must have been removed relatively recently. The rheostat control seems to be entirely missing, with two holes in the front panel showing where it once must have been. The remaining capacitor, feedback and band select controls are intact and appear functional. There is one strange peculiarity on the front panel: The "B+" terminal has mounted under it a piggy-back terminal on a short piece of metal to allow a second connection to be made to that terminal. The biggest surprise, however, is a modification, presumably by a user, to add a third vacuum tube to the radio. That third tube and a transformer are mounted on the back panel outside the case, adjacent to the ½ inch hole similar to the back panel hole for battery leads of the radio above. This third tube is in a socket attached by screws to the back panel and the tube socket. The tube is very delicate, the glass envelope having lost firm contact with its base. The wiring associated with this additional stage is ad-hoc. This radio is obviously missing some things like terminals, but the biggest missing piece is the rheostat. It would appear this radio has been used as a parts source. Is the wooden front panel unique enough to make salvage of this radio worthwhile?

4. **Crosley 52** (serial 29356 O): This radio is a three tube model, having two stages of audio amplification. The most obvious problem, apparent immediately, is that the control knob for the "book" capacitor, used for tuning, is entirely missing. The control shaft projects out from the front panel's surface. I didn't see signs of a break. The large knob (marked in 0-100 graduations) detaches and can be reattached. These knobs are secured with a set screw.
The terminals for "G" (Ground), "B45+," and "Output" are missing their screw tops. This model radio has two rheostats. Both and the band selector switch and the feedback control seem mechanically functional. There is a hole on the front panel about top middle where a screw must have originally been securing the first transformer. (The screw is still present on the next radio below.) Nothing seems particularly amiss inside the cabinet. This radio does have a rear hole about ½ inch in diameter, presumably for ventilation, rather than for wires as in the third radio. The cover is a bit warped, as is true for most of the others, but more apparent in this larger radio.



5. **Crosley 52** (serial 35594 O): This is another of the three tube model as above. This one is missing the knob for the band selector, as well as the band selector arm that makes contact with the nubs to connect at the various inductor taps. It does have the capacitor knob, though, so between these two radios a complete one should be possible. The other controls (feedback, capacitor, and two rheostats) seem functional. All of the terminal screws are present, as well as the screw missing in the middle of the front panel on the radio above. There are significant differences between this radio and the one above. In the above radio, both audio transformers appear to be identical, having the Crosley logo, and seem to be the same as the transformers found inside the Model 51 radios. For this radio, the final transformer is larger, is of different shape, and does not have the Crossley logo, at least where I could see it. There are some vacant holes in the front panel that must have originally attached the second transformer, and new screws to attach the current one. Where most of the internal wiring in the radio above is in the form of bus bars, this one mostly uses hook-up wire. Also remarkable is that all three vacuum tubes are of a different and smaller form than those of the other radios. They are cylindrical rather than larger at the top, and seem to plug into adapters that in turn plug into the original radio tube sockets. The two audio tubes have paper labels with lettering in red, "Use in last audio stage only." The detector tube lacks that label. Again, the tubes were reluctant to be removed. I didn't force the issue, so their identification remains a mystery at this time. They appear to be about the same size and shape as Octal "GT" tubes, perhaps slightly smaller in diameter, and longer than some.

For reference, here is an illustration of the Crosley 51, identifying the various parts. The Ace V is similar but has no audio amplifier. The 52 adds a second amplifier stage and is longer.

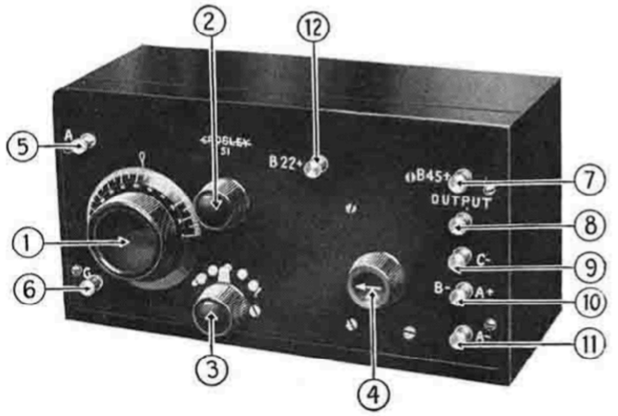


Figure 4

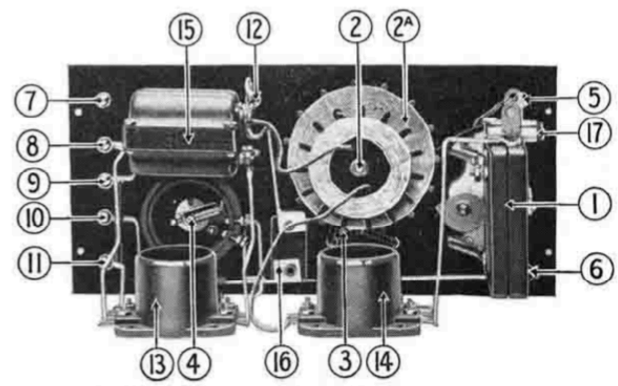


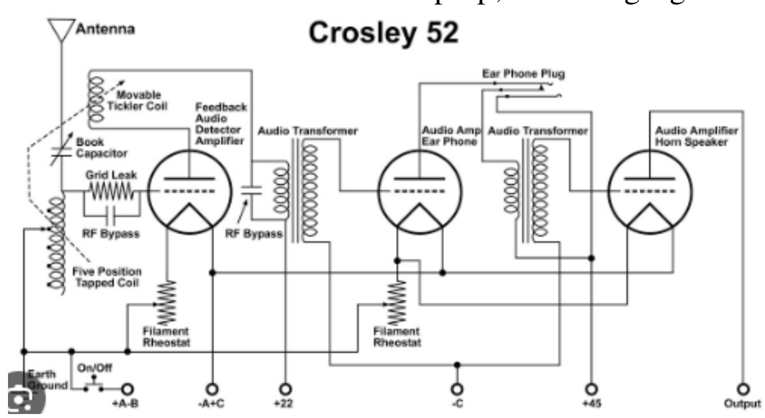
Figure 5

Front and Rear View of Crosley 51

INDEX OF PARTS

1. Variable Condenser and Knob.
2. Tickler and Knob (Varind.)
3. Tap Switch and Knob.
4. Rheostat and Knob.
5. Antenna (Aerial) Binding Post.
6. Ground Binding Post.
7. B45 — Terminal and Red Cord Head Phone Terminal.
8. Black Cord of Head Phone Terminal (Plate Connection.)
9. C—(Minus) Binding Post.
10. B—(Minus) and A + Binding Post.
11. A—(Minus) Binding Post.
12. B22 + Binding Post.
13. Vacuum Tube Socket.
14. Vacuum Tube Socket.
15. Transformer.
16. Phone Condenser.
17. Grid Condenser and Grid Leak Holder.

The schematic for Crosley 52 is shown below. The ACE V and model 51 are similar except for having none or just one audio amplifier stages. Some instructions for the use of these radios call for a 90 Volt B+ (instead of 45V) and the optional addition of a C battery. Whether that is appropriate apparently depends on the vacuum tubes chosen, with the lower B+ being used with certain vacuum tubes that have nominally 1.1 Volt filaments. Note also that the schematic implies that the audio transformers are step-up, increasing signal Voltage.



Finally, it should be mentioned that a few loose parts, including a small knob, a binding post, and several screws for a front panel were found loose in a plastic bag inside the fifth radio. The knob seems to be for the band selector switch, but lacks the metal contact arm.

General Observations:

The condition of these radios seems mostly intact, but enough parts are missing that it would be difficult to get all of them working unless a source of replacement parts was available, which is doubtful. The most unique of all of these radios, the wooden front 51, is also the one most heavily modified (with that extra tube attached), and is also missing the most pieces of hardware. Three vital pieces are each missing on some one particular radio: the capacitor tuning knob, the band selector knob and contactor, and a rheostat. So, fixing all five isn't possible. It remains to be assessed which should be saved, if possible. The natural preference would be to save the 52's, since with the extra audio stage (and an appropriate speaker transformer for modern speakers) they ought to be able to drive a small speaker. The one tube ACE V can only be expected to drive high impedance earphones, and anything more than that is iffy for the 51's. (Yes, I did see a U-Tube demo of a Crosley 51 driving an antique horn speaker.) The two 51's and the 52 with the replacement transformer seem the most heavily modified. All this suggests that the 52 with the original transformers may be the best candidate for a first attempt to get one of these radios working. It's main fault is the missing capacitor tuning knob.

Radio #4 (**Crosley 52** serial 29356) **Measurements and Characteristics**:

Extracting the electronics from the case is easy. The four corner wood screws are removed, and all the electronics slides out of the box along with the front panel. The tube sockets are not attached to the cabinet, nor is anything else. The bus bar circuit construction keeps the whole assembly mechanically coherent. With the electronics out of the case, an attempt was made to remove or examine the tubes, but they still are not inclined to move. The second audio amplifier has a bit of its label remaining. Something that may have been a logo, a script "C" (for Crosley?) was found on the crown of the detector, but neither of the other tubes.



With power off an no attachments, component values were measured with an Extech LCR Meter (model 380193) at both 120 Hz and 1 KHz. For the transformers coils DC resistance was also measured with a METEX 4650CR DVM.

Filament circuits: The off/on switch resistance, initially 3.7 Ohms, was worked a bit and later registered .19 Ohms, considered acceptable. With both filament pots off, 726 K Ohms was measured across the A supply. Rotating the detector supply pot (only) gave inconsistent and high readings, reaching a low of 38 Ohms at about 80% rotation. Leaving it open and rotating the audio pot also gave inconsistent high readings but reaching a low of 107 Ohms. Clearly both potentiometers need work to restore them to proper operation.

Tuning Circuit: Measurements were made at all five taps of the tuning inductor, first with the knob all the way clockwise, then all the way counterclockwise. As viewed from inside, I arbitrarily labeled the stops as #1 (extreme CW) to #5 (extreme CCW). Inductance measurements were made at 120 Hz and 1 KHz, the two frequencies available for the meter. Making both measurements suggests the trend of inductance versus frequency, although this is not inspiring of analytic confidence when extrapolated to radio frequencies. Still, it is useful for comparative purposes.

Tuning Inductor Measurements (Scaling as auto-selected by the meter, mH or uH.)

From extreme CW (ground to #1)			From extreme CCW (ground to #5)		
Measured at:	120 Hz	1 KHz	120 Hz	1 KHz	
#5	.315 mH	307.2 uH	.006 mH	9.7 uH	(should be zero)
#4	.164 mH	155.8 uH	.044 mH	41.9 uH	
#3	unstable, couldn't read		.137 mH	.137 mH	
#2	.164 mH	155.8 uH	unstable – couldn't get reading		
#1	.27 mH	45 uH	.346 mH	335.1 uH	

These readings are problematic, but seem to suggest the inductor has an overall inductance somewhere around 330 uH overall, perhaps a bit less to account for frequency effects. It was unknown why instability was encountered at #3 and #2 terminals. The feedback coil was well removed, at maximum extent, and the tubes were not operating. It could be the contact was problematic. There is a loose wire, presumably to one of the coil taps, that was discovered, and it is probably part of the reason for these inconsistencies. The coil will probably have to be removed to fix this fault. (Not up to that yet.) There is some parasitic inductance from the meter leads that was not accounted for.

The tuning "book" capacitor was measured between the antenna terminal and the connection to the coil and connection to the detector grid. When maximally open, the capacitance was measured 46 pF at 120 Hz and 36 pF at 1KHz. That includes about 6pF for the meter and leads. (Inductors typically vary much more than capacitors with frequency.) When maximally closed, the capacitor measured 475 pF at 120 Hz and 460 pF at 1 KHz.

The grid leak resistor in parallel with the bypass capacitor registered as 440pF and 2.2 M Ohms. These values seem satisfactory. The actual capacitor would be somewhat less due to stray capacitance. The "tickler coil" (which gives the feedback) in its most extended position registered as .078mH / 3.31 Ohms at 120 Hz and 76uH and 3.23 Ohms at 1KHz. That seems reasonable given the observable difference in size from the tuning coil, both being of similar form.

The radio has two transformers. With the tubes not operating and power supplies open, the transformer windings could be measured as if isolated, since the other winding would be essentially open. The measurements of inductance and resistance are given in the table below:

Winding:	L(120Hz)	R(120 Hz)	L (1KHz)	R (1 KHz)	R(DC)
First transformer (nuts up)					
Primary	6.95 Hy	1611 Ohms	4.27 Hy	10900 Ohms	633 Ohms
Primary*	7.26 Hy	1780 Ohms	4.34 Hy	11500 Ohms	*: remeasured
Secondary	93.19mH	67.7 Ohms	51.12 mH	207.4 Ohms	51 Ohms
Second transformer (screws up)					
Primary	323.5 mH	166.4 Ohms	161.8 mH	617 Ohms	90 Ohms
Secondary	5.13 Hy	1490 Ohms	2.67 Hy	7900 Ohms	515 Ohms
Transformer from #51 radio (number 3) (screws up) – but circuitry is suspect					
Primary	1.49 Hy	627 Ohms	2.12 Hy	5070 Ohms	534 Ohms

These results were so surprising that I remeasured the first transformer primary and also checked the primary on one of the model 51 radios. (The other 51 transformer had an open primary.)

What is surprising was that I expected, based on the schematic and experience with other radios, that the transformers would be step-up, in order to convert current gain into additional Voltage gain. That would be achieved by a turns ratio of one to many from primary to secondary. (The turns ratio should be about the square root of the inductance ratio. That would be about a factor of 9 (1/9 from primary to secondary) for the first transformer, and a factor of 4 for the second one. Whatever Voltage gain these vacuum tubes have is probably less than a factor of 10. (The mu of a #26 is about 8.) How can this radio afford to be cutting the Voltage gain by an order of magnitude in the first transformer? In the Radiola 17 I have, the RF transformers are of a turns ratio about x10. The detector output transformer seems even bigger than that.

Could it be that the first transformer is backwards? I noticed that for the detector output transformer, the screw nuts were on top, while for the inter-stage audio transformer the screw heads were up. Was that indicative? The other 52 radio had just one Crossley transformer, and it had an open primary. I checked the transformer primary of the two good 51 transformers and I found that that transformer primary also had a high inductance, like the 52 I'm working on. And, it had the screw heads up. So, that's not an indicator. It might be significant that a lot of the nuts for the transformer terminals on the 52 were loose, as if someone had reason to loosen them less than a century ago. Might the transformer have been replaced?

When I first looked over all of these radios, the transformers with the Crosley logo all looked identical, and served similar purposes, so I assumed they'd have similar characteristics. At this time, that doesn't seem to be the case. I have not found any identifying marks on these transformers so far other than the logo on the top, with the terminal markings "P1, P2" at one end and "S2 S1" at the other where there are no terminals on that side. On the bottom is the same enclosure plate with the logo, but the end with "S2 S1" is at the end with the terminals. So, maybe these radios do need a very high impedance looking into the first coupling transformer. Without knowing what the tubes are I have not been able to try simulation or analytic methods to test that idea.

I've got to try to get those tubes out. Ah! Examining the ACE V (with no tube), I can see that the tubes must be twisted out, like a bayonet light bulb. Knowing that, these come out easily. I will call the detector tube V1, the first audio stage V2, and the output tube V3.

V1 (detector): Cunningham CX-301A labeled on the base. This tube has a 5V filament drawing .25A, allows a plate current up to 3mA. At 90 Volts with 2 mA the transconductance is 725 micromhos. The mu (maximum Voltage gain) is about 8. Grid-plate capacitance is 8.1 pF. (The filament resistance measured about 10 Ohms cold.)

V2 (audio amplifier): Marathon Type M 201A. This tube also has a 5V filament at .25A, designed for 22 ½ to 135 Volts plate Voltage, as stated on the tube base. It is very similar to the 301A above. It doesn't have the usual bigger filament pins. The filament seems to be burned out. **DEAD**

V3 (output): Still unknown, but made by Perr[… ?], a company with a serif P logo. From the paper label it is identified as a power a[mplifier] type (inferred). The filament measures only about an Ohm, so this may be a 1 Volt tube, or perhaps has a shorted filament. That's inconsistent with the data of V2, which shares the same filament Voltage. So, it would seem that at least two replacement tubes will be needed to get this radio working.

As a summary, two replacement amplifier tubes of about 5 Volts are needed. A knob is needed for the tuning capacitor. There's a broken connection on the tuning inductor that needs to be fixed. The rheostats need to be restored to good operation. There may be a problem with the first transformer. The missing terminal screws need to be replaced.

More about inter-stage transformers: The Hammond 124C is considered a usable replacement by some hobbyists for replacing the Crosley transformers. Being a current commercial product, data is readily available. This transformer has two equal secondaries that can be put in series or parallel. In series, the primary impedance of 10K gets turned into a secondary impedance of 90K, which implies a 1:3 turns ratio, with a higher Voltage on the secondary than the primary by a factor of 3. This transformer is designed specifically to be a tube inter-stage transformer, so this would seem to be normal. (It can handle 5 Watts. Other variations have implied Voltage ratios of 1.5 (D), and 1.0 (F).) So, we would expect the transformers in these Crosley radios to be step up transformers, not step down. It might be that the very high input inductance and impedance is a sign of a fault, but the DC resistances are consistent. Some experimentation is going to be needed to figure out what is going on.

The Vacuum tubes of other radios:

Now that I understand how to get the tubes out of sockets, a survey of those in the other radios is needed.

1. **The ACE V** radio does not currently have a vacuum tube at all.
2. **Type 51** (serial number unknown)

    Detector tube: Silvertone 201A – 3AV (It is not known what the 3AV means. This is a basic 5V .25A triode like the one in the #52 being examined. It seems to have an open filament. This tube has the later "coke bottle" shape. **DEAD**

    Amplifier tube: Wards 01A This is a triode similar to the 201A. The filament registers as about an Ohm, so although it seemingly should be a 5V tube, it might be 1 Volt. Coke bottle shape.
3. **Type 51** serial 148487 E

    Detector tube: Trego 201: This is similar to the 201A above. Although supposedly a 5 Volt tube, the filament registers only about an Ohm. This may be a 1V tube. The getter material shows peculiar discoloration in oval "rainbow" patterns on opposite sides of the envelope.

    Amplifier tube: CK 201A: Similar, with about an Ohm resistance for the filament.

    Output tube: This one was too delicate to disturb, since the envelope has come loose from the base.
5. **Type 52** serial 35594 O

    Detector tube: This is a small tube inside a standard 4 pin adapter base. The only label visible reads, "[B]ecause it is a Quality Product." The label is upside down, and missing whatever was written on the label further up. The adapter has a small set screw that, when removed, allows the smaller tube to be extracted. It is a Cummingham CX299. Its filament registers open. I had not seen a tube of this form factor before. The adapter simply has holes for the tube's pins to stick through, and provides a larger diameter base with bayonet to work in the Crosley sockets. **DEAD**

Amplifier tube: Cunningham CX-220 This is a tube of the same physical form as that above, also with an adapter that allows it to fit into the Crosley sockets. On the tube is a paper label “”For Use in Last Audio Stage only.” **DEAD**

Output tube: Cunningham CX-220, the same tube type as above. But, this one seems to have a good filament of a few Ohms.

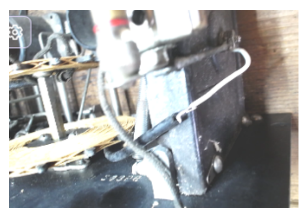
A note about tubes with open filaments: Sometimes the filaments are actually intact. What has happened is the solder joint between the filament lead and the pin fails. This is particularly likely with old 20’s and early 30’s tubes before manufacturing became more mature. It’s possible to re-solder such pins and get the tube working again.

(I have some additional old tubes of this era that might be useful for these radios.)

As a temporary expedient, the dead 201A in radio #4 will be replaced by the 201A (seemingly good) from the amplifier stage of radio #3. So, the detector is a #301A, and both amplifier tubes are #201A.

Repairs and further tests to radio #4 (Crosley 52 serial 29356 O)**:**

The most obvious fault that needed fixing was the broken wire from the tuning inductor. After dismounting the tuning coil assembly, it was seen that the loose wire was apparently the outermost wire, the terminus, of the inductor coil. It needed to be reconnected to a terminal of the tuning capacitor. That was accomplished by adding an AWG 22 wire from the fixed terminus of the tuning capacitor (where the bus bar to the RF bypass and grid leak resistor goes) up and over the tuning capacitor, where it was soldered to the bare end of the inductor wire.



A new set of inductance measurements were made, this time at just 1 KHz, to check the coil repair. Inductance was measured from the stationary tuning capacitor terminal to ground with the vacuum tube removed and no antenna. A measurement was made at each tuning switch position, #1 (fully CCW) to #5 (fully CW) (I think this is the reverse ordering from what I did before, made from the rear view.) The tickler coil was fully away from the tuning inductor. The capacitor was at its most open position. The (AC) resistance measurements don’t quite make sense. Initially, the #3 and #4 readings were unstable. The contacts and the wiper were sanded down, and afterward gave the good values shown. This explains those earlier bad results.

Inductor switch	Inductance (1 KHz)	Resistance (1 KHz)
#1 (max CCW)	52.1 uH	1.33 Ohms
#2	165.2 uH	5.58 Ohms
#3	306.7 uH	4.38 Ohms
#4	442 uH	3.92 Ohms
#5 (max CW)	555 uH	18.3 Ohms

The second repair was to restore the potentiometers to working order. Each was disassembled by removing the wiper from the shaft and sanding the spring that applied wiper pressure against the resistance winding. The inside race of the resistance coil was sanded. Both potentiometers were tightened up. That proved to give relatively smooth resistance transitions as monitored by a digital Ohm meter. The resistances varied between zero to about 23 Ohms for each potentiometer. A filament at 5V and 1/4A would be the equivalent of about 20 Ohms hot, or two together (paralleled) 10 Ohms. So, about 20 Ohms for the potentiometers is a reasonable choice for a 6 V battery supplying 5V tubes.

The opportunity was taken to make some more measurements concerning the two transformers. A signal generator was set to produce 400 Hz at approximately 1 Volt unloaded. Measurements were made with a DVM, so these Voltages are RMS. When connected to the primary of the detector to audio stage transformer (henceforth T1), the signal was reduced to .607 V. The unloaded output at the secondary was then measured, and found to be .565 Volts. That is, the transformer Voltage multiplication seemed to be near unity. As a check, the signal generator was connected to the secondary. Loaded, the Voltage was .561 Volts. The primary side registered .556 Volts (unloaded). So, indeed, the transformer seems to be about one to one. A similar measurement was made on T2. Unloaded the signal source registered 1.015V. Loading the primary of T2 gave .584V. Under that condition, the unloaded secondary registered .570V. So, whatever the earlier measurements of inductance, the transformers by this test seem to be about one to one. This information is contradicted by other data taken later. It has been noticed that some of the screw terminals of the transformers were loose and were tightened up.

Filament test: With three good tubes installed (301A detector, 201A's for audio amplifiers), a filament test was run. A Lambda LP410 FM regulated supply was set to 4 Volts and connected to the A+ and A- terminals. The potentiometers were set to "off." The power supply was verified as putting out 4 Volts. The radio power switch was turned on. This switch controls just the A (filament) supply, since if the tubes are not active, the B+ supply is effectively open. The detector potentiometer was turned on, with the pot near its largest value. The power supply current meter verified that current was flowing. The detector wasn't visibly glowing. The power supply was turned up to 5 Volts, resulting in a visible glow (with the lights off) and the potentiometer was adjusted to give filament terminal readings of -5V and -1 Volts (4 V across the 5 Volt filaments. The glow was now readily visible. That was followed by doing the same with the amplifier potentiometer. The envelope of the output amplifier tube was so covered with gettering material that it was hard to see the glow, but it was seen and verified. The potentiometers were roughly in the middle of their possible range. I considered this a successful filament circuit check.

Preparations for AC tests:

A set of high impedance headphones was available. In addition, an orphan audio output transformer, perhaps from an All American 5 type receiver, was available to drive a modern low impedance speaker. The transformer registered about .43 Ohms DC for the output winding and 178 Ohms for the primary. Inductance measurements were 17.1 mH secondary and 1345 mH for the primary. That would suggest a turns ratio of 9 if that can believed. At any rate, it was the transformer available. The speaker was 8 Ohms rated 5 Watts, so probably rather inefficient. It had a heavy magnet. The combination of transformer and speaker will be tried as an output load.

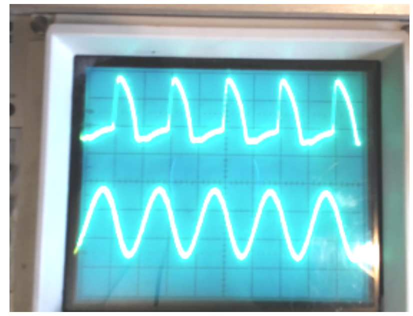
A 45V B+ power supply available was a MeanWell HRP-100-48. The supply has an adjustment that allows the output Voltage to be set at 45V. Initially just one of these will be used supplying both the VB22+ and VB45+. Later another similar supply will be added to boost the B+ Voltage to 90 Volts. (I didn't get to that; the radio wouldn't be much louder at 90V.)

A signal generator is available to supply 400 Hz modulated RF at various frequencies, an EICO model 324. This same signal generator has been used for previous radio work and seems to be reasonably accurate, within a percent or so, for frequency. The output is not very symmetric, generating higher harmonics. Still, the instrument should be sufficient for making basic observations. In the past a resistor of about 1 Meg was used in substituting for a signal from the antenna. The oscilloscope used is a Tektronix 465B analog two channel (chopped) oscilloscope. Times 10 probes were used. The set-up is shown in the picture below. (The oscilloscope is below the table.)

A preliminary check of the antenna / tuning circuit was made with the radio unpowered. Setting the signal generator to about 1 MHz, unmodulated, with the amplitude at 2V peak, the signal was injected to the antenna front terminal through a 1M Ohm resistor. The tickler coil was well away from the tuning inductor. The resonant point in the radio tuning was found with the inductor selector on the rightmost (#5) terminal and the capacitor at "70" on the tuning dial, a position most of the way toward closed. The sinusoid signal across the inductor registered 1.1V p-p (550mV peak) With the frequency set to 900KHz, the amplitude on the tuned circuit was reduced to .15V p-p. Closing the capacitor to 100 increased the amplitude to .25V p-p. It seemed that 900 KHz was below the minimum frequency this receiver could be tuned to. Increasing the frequency to 1100 KHz did not reach a maximum in the band available to setting #5 either. With the inductor selected to #4, a peak was reached at a capacitor setting of 93. At 1200 KHz, a peak lay beyond reach with the inductor set to #4. But, with the inductor set to #3, no satisfactory peak was found there either, or on #1.

Reversing the process, the radio was set to each of the switch positions and the capacitor at 0 and at 100, and the resonant frequencies recorded. The capacitor could go a bit more beyond 100, so a third reading was added for each band beyond 100. Going beyond 0 added a 4^{th} value.

Inductor switch	Capacitor max ~115	Capacitor at 100	Capacitor at 0	Capacitor beyond 0
#5	960 KHz	970 KHz	1020 KHz	1030 KHz
#4	1070 KHz	1080 KHz	1120 KHz	1140 KHz
#3	1260 KHz	1270 KHz	1330 KHz	1340 KHz
#2	1630 KHz	1640 KHz	1700 KHz	1710 KHz
#1	2420 KHz	2430 KHz	2500 KHz.	2500 KHz



The picture at right shows the first reading, at 1 MHz, With the inductor on position #5 and the capacitor at "70." The oscilloscope was set to .5 usec per division, and A (the signal generator) was displayed at .1 V per division (so, with a x10 probe, 2 Volts peak on the positive swing) and channel B, below, at 50 mV per division (.5V per division, or 1.1V p-p, after taking into account the x10 probes. (Note the significant asymmetry of the driving signal from the signal generator, a characteristic of these units.)

It was expected that this would represent the tuning of the receiver in the various bands. If so, this radio has a big problem: The bands are narrow and not overlapping. Broadcast band stations below 960 KHz cannot be received, and those from 1030 to 1070, 1140-1260, and 1340 to 1650 cannot be received, since they are outside any band.

The amplitude at peak was consistently around 1 V p-p on all bands except the last, where it was about .5V p-p.

Assuming that the capacitor maximum was, as measured at 1KHz, 450 pF, and the minimum was about 30 pF, something is obviously wrong. The frequency response seems to indicate a much narrower Capacitor range. Taking the data from terminal 5, calculating the implied inductance for 450 pF at 960 KHz implies an inductance of 61 uH. Yet, about 555 uH was measured at 1 KHz. Calculating the implied inductance for 1030 KHz and 30 pF implies an inductance of 796 uH. But, the inductance should not change significantly between these two closely spaced frequencies. What could be making the difference? One: The capacitor measurements had something up to 10 pF parasitic from the meter. The current test – includes the vacuum tube! It's still in the socket, but not active. And the oscilloscope probe.

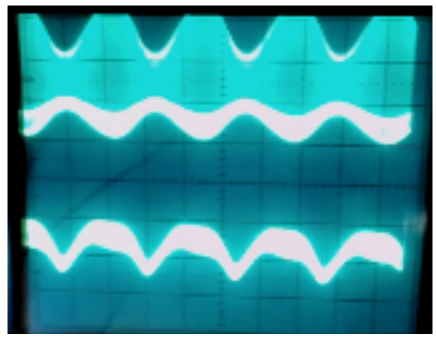
With the vacuum tube removed, the resonant frequencies for inductor terminal 5 change to frequencies 1200 KHz at minimum (up from 1030), 1100 KHz at maximum (up from 960). An upward shift is expected for something on the order of 11pF grid to other electrodes capacitance that is now absent. The tuning range becomes somewhat larger. With the vacuum tube active, and generating positive feedback, the effect is to add a negative capacitance equal to the grid to plate capacitance times the gain (plus 1), a reverse Miller effect. With a Voltage gain on the order of maybe 5 to 8 and a grid-plate capacitance of 8 pF, that's a significant effect that will make the performance measurements with the radio unpowered essentially meaningless.

Furthermore, what about the oscilloscope probes? These were x10 probes apparently meant for medical applications. They were what I could find at the time. Doubling the scope probes on the tuning circuit shifted the frequency range for inductor #5 to a range of 880 KHz to 920 KHz. That's a big effect! I used the LCR meter to measure the probe capacitance while connected to the oscilloscope. I measured 33.4 pF! That's about the same as the measured tuning capacitor minimum. So, that would affect both the frequency minimum (making it lower) and the range (making it narrower).

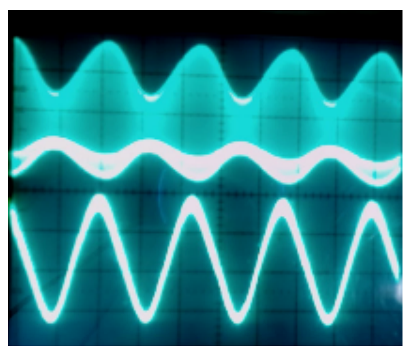
So, the data from the unpowered tuning resonance exercise is essentially meaningless. It may show, however, that absent the regenerative effects (and the reverse Miller effect on the grid-plate capacitance) this single vacuum tube detector stage, with its "book" capacitor, might have been ineffective. Let's see what happens with power.

The radio was left in the same test configuration as before, with the signal monitored at the detector output (the top of the inter-stage transformer primary). The signal strength at the output of the signal generator was initially reduced to .1 V peak. The A (filament) power supply was left at 5V (rather than 6V) to ensure that the filaments could not be pushed above the tubes' rated 5V. The filament power to the detector was turned on and set to put 4 V across the filament (the controlled pin Voltage at -1V). The tuning was left at maximum capacitor (a setting imagined as 115). The signal amplitude was turned back up to 2V peak (before the 1M resistor) in order to see a signal at the detector circuit output.

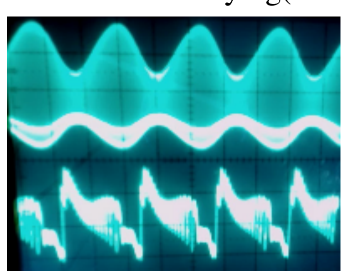
The signal generator was adjusted to show a peak signal out at 1080 KHz. It was just 60 mV p-p (RF). The detector filament was then turned up to 5V (actually 4.8V). That had no effect on the (RF) amplitude visible at the output (at the transformer). The expectation was that there would be a larger signal output. The regeneration knob was pulled in and back out without seeming to have an effect on the signal amplitude. It was noticed, however, that the phase of the output shifted from about 200° (lag) all the way out to about 340° (lag) all the way in.

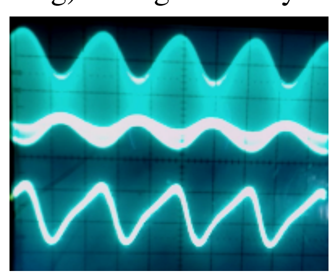


A large modulation of about 50% at 400Hz was added to the output of the signal generator. The RF is still present at the detector output as earlier, now superimposed on a 400 Hz signal. The audio is about .1 V p=p. (In the image shown, signal A (radio input) at 1V/division, B is .1V per division, scanned to make 400Hz nearly stable.) RF at 1080 KHz. Very little of this signal made it to the transformer secondary, and nothing to the output of the first audio tube, even with the filaments turned up to 5 Volts. Oh. The B+ supply was not on!



With B+ on and just the detector stage with active filament power, a 400 Hz signal appeared at the detector output. The 400 Hz signal was 6 Volts p-p (after accounting for the x10 of the probe). This was at 1080 KHz as before. This peak output was reached with a filament (R side) Voltage of -2.18V (3.82V on the filament). Beyond this filament Voltage, the amplitude of the output signal rapidly decreased. That must have been because the filament bias Voltage with respect to the grid was becoming smaller in magnitude, so while amplifying the RF, the tube was not rectifying(detecting) the signal nearly as well. This, by the way, was with minimum feedback (knob fully pushed in).





The tuning capacitor was changed to a minimum value, and the frequency changed to 1160 KHz to give an audio "peak" but it was a very ugly peak (see picture). Twiddling the filament to reduce the filament Voltage reading (-2.24V, so 2.76V filament Volts) cleaned it up (mostly), giving about 4V p-p (at right above).

Clearly this radio is very sensitive to the detector filament Voltage. I'm operating at 45V for the detector; it might work better at 22 ½ Volts. But, maybe that's why this radio (unlike the 51) gives a separate rheostat for the detector stage. It's very much needed.

Returning to 1080 KHz and maximum capacitance, an effort was made to adjust the feedback. As the feedback was drawn out (closer to the main inductor), the Audio decreased, and the RF fed through increased. Had the frequency changed? Yes! Adjusting the signal generator downward gave a peak at 1070 KHz, slightly lower. The feedback was increased some more, and now the cleanest audio signal was at 1060 KHz. Drawing the feedback closer didn't help in either frequency or amplitude. The largest peak audio signal at 8V p-p (more triangular than sinusoid) was at 1070 KHz with the feedback control at half way. (This is still with the low filament Voltage, now measuring 2.41V)

With this situation on the detector (1070 KHz, 2Vp RF with about 50% modulation, maximum capacitor on inductor setting #5, and about 8V p-p at the detector output, the filaments for the audio amplifier stages were turned on. (A B+ Voltage of 45V was also being supplied to these two tubes.) As soon as these tubes were turned on, the detector output dropped greatly to about 1 Volt. (A slight frequency adjustment to about 1080 brought it back up to 2V p-p. An extremely slight filament adjustment gave about 3 – 4v p-p (not very stable!). This was with the amplifier filaments barely on, and no signal showing up at the second transformer.

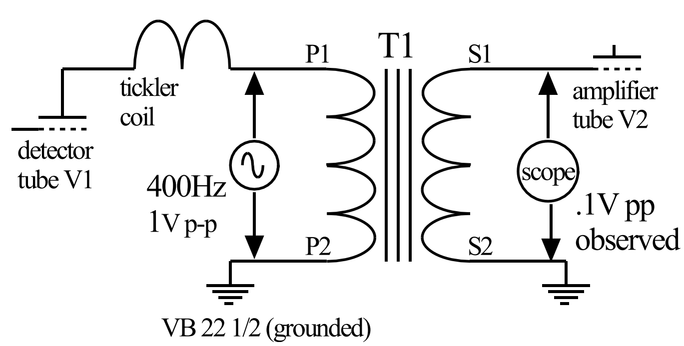
There was no signal at the plate of the first audio tube, and no signal at the grid (the top of the transformer secondary). The grid voltage was about -5V. With the amplifier stage filaments turned off, the grid remained at -5 Volts. Something was clearly wrong that had not been tested for. A short in a tube or in a transformer? Power was turned off.

Tests with signal generator:

The hypothesis "The T1 transformer is backwards" had been posed, based on the fact that one would expect it to be a step-up transformer, but it seemed to be a step-down. To this point tests had been made with the transformer in the circuit.

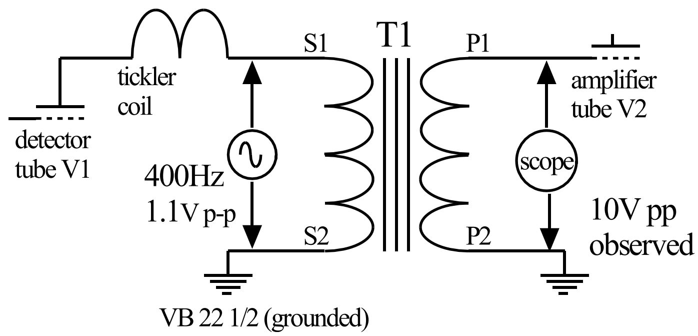
This does imply the transformer must be a step-down transformer in its current configuration. In confirmation, a 400 Hz signal at 1Vp was put on the primary. On the oscilloscope, about .1Vp was observed at the grid to V2, the first audio tube, consistent with a 9.1 turns ration based on the square root of the inductance ratio. With the VB Voltages shorted to ground, no signal was seen at the ground/power secondary terminals.

The transformer was removed, and checked in isolation:



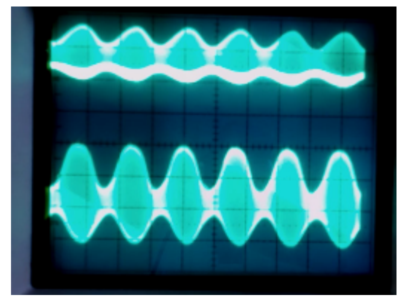
Measurements on T1 Detector to audio amplifier inter-stage transformer:
Primary (as marked):
620.5 Ohms (DC), 4.28 Hy (at 1 KHz)
Secondary:
47.9 Ohms (DC), 51.36 mHy (at 1 KHz).

Now, the transformer was placed back in the circuit with primary and secondary reversed. It was not possible to use the mounting screws (one of which was missing) because in



this configuration the opposite side of the transformer faced the front panel, and that side had no mounting provisions.

The 400 Hz signal was again applied. Its Voltage dropped to .2V p-p due to loading by the (lower impedance) secondary. Stability was found at 1.1V p-p as measured at the transformer. The secondary Voltage was observed to be 10V p-p. That's consistent with the 9-1 turns ratio thought to be characteristic of the transformer, notwithstanding that earlier measurements with the transformer in the circuit had seemed to indicate otherwise.



Next, the vacuum tubes were restored, and the Radio Voltages applied, with the signal generator and tuning set for 1180 KHz (tuning contact #5, maximum capacitor). Only the detector circuit filament was turned on, with the output of the detector stage monitored. What was observed was that the detector stage was acting as an RF amplifier, producing no demodulated signal at all. It was inferred that the detector load had to be high impedance in order to get demodulation. (This might have been an overly hasty conclusion. We'd see.)

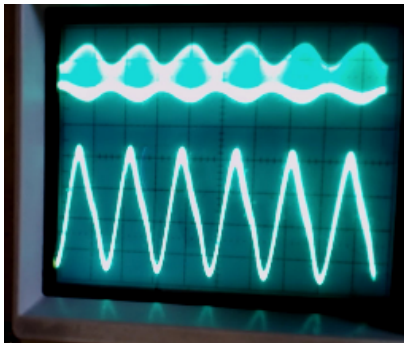
Radio Testing with the Signal Generator:

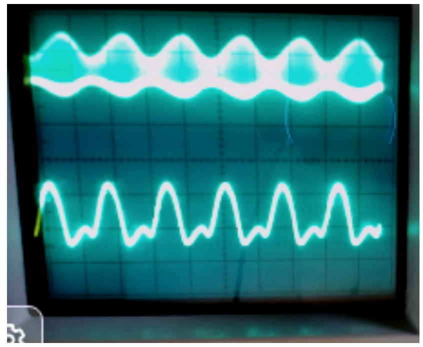
With the T1 transformer back in its original configuration, the radio was left at 1090 KHz, tuning inductor setting #5, and maximum capacitance (for minimum frequency). Modulation at 400 Hz was set to about 50%. The RF peak to peak signal was about 2 Volts, that signal being connected to the antenna terminal through a 1 M Ohm resistor. The detector was initially set for -3.07V on the filament (VA=5.27V). A demodulated output (at T1 terminal P1) of 1.2V p-p was observed. Manipulating the filament Voltage slightly gave a signal out (at P1) up to 3V p-p. The size of the demodulated Voltage is very sensitive to the filament Voltage. (More about that later.)

The amplifier filament currents were turned on. At the first audio tube grid the signal was about .25V p-p, reasonably consistent to the degree possible with about a 9-1 turns ratio on T1. The plate Voltage was .08V p-p, actually less than that on the grid. The secondary Voltage, the grid Voltage of the output tube, was about .7V p-p, again, consistent with a turns ratio of about 1-9. A tone could just barely be heard at the speaker. The Voltage to the amplifier filaments were turned up to the full (rated) 5 Volts, giving a considerably louder signal. After readjusting for maximum modulation (still around 50%), and maximum detector out, the following signal; path Voltages were noted:

Detector output (T1:P1) 3.5 Vpp
First Audio output (T2:P1) .1Vpp
Audio Output (plate of V3) 1.5Vpp (with significant distortion)

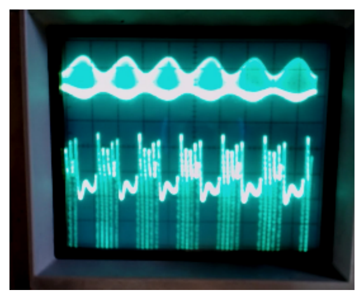
Given the transformer configuration of T1, this seemed like about the best that could be done under test bench conditions. The figures below show the detector output and audio output.





While the radio was in this configuration, an attempt was made to establish the band limits for each inductor setting. The feedback was left out as far as it would go (minimum) and the signal generator was tuned to get maximum audio signal at the detector output for both the minimum and maximum capacitor settings. This frequency measurement was not distorted by extra parasitic tuning capacitance from the probes as had been true of earlier measurements.

Tuning inductor:	Lowest (max capacitor)	Highest (min capacitor)
#5	1085 KHz	1180 KHz
#4	1210 KHz	1300 KHz
#3	1410 KHz	1515 KHz
#2	1800 KHz	1920 KHz
#1	~2600 KHz	~2620 KHz



In doing this testing, I had great difficulty getting acceptable audio demodulation, especially at the higher frequencies. Yes, I could hear tones in the speaker, but the waveform at the detector was remarkably other than sinusoid. Here’s an example (#4 1210 KHz iirc). The detector filament had to be twiddled carefully to get even this good of a signal, and for many settings the demodulator didn’t – it behaved like an RF amplifier producing no demodulated tone at all.

The extreme sensitivity to the detector filament would seem to be due to a secondary effect, that the changing filament Voltage not only changes the tube transconductance characteristic due to the temperature of the cathode, it also changes the DC Voltage of the filament with respect to the VC (grid bias Voltage). In theory the grid leak resistor should compensate for that. But, one end of the filament is as much as two or three Volts different from the other, with no bypass. So, the effect is complicated. As filament current goes up, the difference between the two ends of the filament gets larger. I’ve been operating the filament supply at 5V rather than 6V as an element of caution. But that may make the detector bias situation even more delicate than 6V would be. My hypothesis is that the tube has a “soft” cutoff due to the variation in filament Voltage with respect to the grid. With a sufficiently positive grid Voltage the tube stops acting as class B (needed for detection) and behaves like a class A amplifier. As it does so, transconductance increases, and then the tickler coil has a chance to kick in and make things oscillate (despite being at a maximum distance from the tuning inductor). (Using tubes with a 6 Volt filament may make this issue worse, though making the use of a C battery in the amplifier section less necessary.)

An attempt was made to operate the radio as a radio from available (daytime) local signals rather than the signal generator. The signal generator was left off, and the 1M Ohm resistor replaced by a wire antenna about 20 feet long at second story height. The radio was left on inductor terminal 5. The state of the detector circuit and the audio output were monitored with the oscilloscope. The tuning was left on inductor setting 5, and the capacitance varied downward from the maximum position. Something could be heard around capacitor setting 93, but it was not loud enough to hear anything discernable. The detector filament supply was varied to avoid oscillation, which seemed more likely at frequencies where there seemed to be some sort of signal. It was difficult to interpret anything of significance on the output. Playing with the feedback never seemed to help. I concluded that there simply wasn't enough gain in the audio amplifier to hear anything, even though sometimes the detector seemed to think there might be a signal. This primitive antenna was sufficient to pull in signals with the Radiola 17, albeit a 6 tube receiver (7 including the power rectifier) compared to 3 with this Crosley 52.

So, maybe that T1 transformer is backwards after all? It seems worth a try to reverse it and try again. I'm about out of ideas. A short while later: With T1 reversed (step -up) the detector stage produces no demodulation. At whatever the filament Voltage, I'm seeing nothing but modulated RF at the transformer input. (And, by the way, the RF bypass across the transformer on the detector side now seems to be broken. The bus bar came loose from the component. Oh – worth noting, this capacitor seems to go to ground, not B+ 22 ½, as shown in the schematic.)

Conclusion (for now):

I've seen this radio on the edge of working. I can get a signal from a signal generator and the modulated tone makes it all the way to the speaker and is audible. I have not been successful with actual radio signals. While there has been evidence that I've detected a station, nothing can be heard well enough or loud enough for identification. There are still numerous aspects of the performance of this radio that are not understood.

Some analytic perspective:

The CX 301A triode data sheet has some information that helps. For a detector stage, grid leak bias with 1-5 Megohms and RF bypass of 250 pF is recommended, with up to 45V plate supply. The grid return should go to the positive filament terminal, which it does. With VB of 45V, and 5V at the filament, cutoff is somewhere around 3 Volts. (I've been running much lower filament Voltages.) On positive grid swings up to 0 Volts the plate current swings as much as to 2mA. It's worth noting that the plate resistance for this tube at 2mA is 12K Ohms, increasing at 1mA to about 16K. So, that's why a high impedance input for the primary of the inter-stage transformer is needed. As I saw, with the transformer reversed, the signal voltage at the transformer dropped greatly. The mu (ideal Voltage amplification factor) for these tubes is about 8 over a wide range of currents. So, if the two transformers cancel (one is 9-1 and the other 1-9) then the amplification would be ideally around 64, in practice considerably less, but still hopefully enough to give several Volts at the output to drive a speaker. The critical issue is what signal Voltage can be produced at the detector output. Values up around 4V p-p were seen, but that may only be because driving the radio with a 2V p-p signal through a 1 Meg resistor is much more signal than can be expected in practice.

Q Point Data:

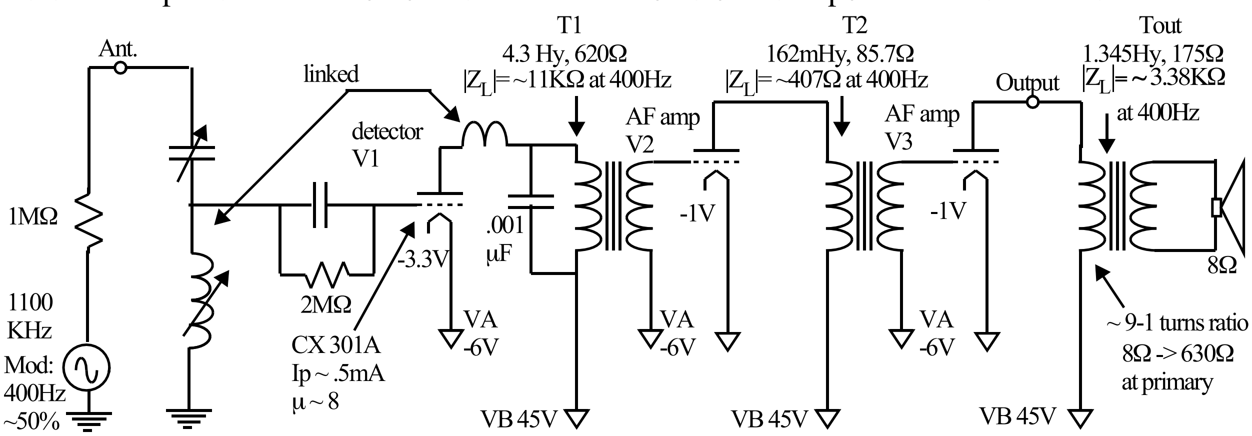
Back on the signal generator with the radio operating at its seemingly best point, I collected data that would establish the operating point for each of the vacuum tubes. One repair made was to add a .001 uF mica capacitor across the T1 primary. It was clear that the RF bypass capacitor was broken. (A 360pF capacitor was tried first, but the .001 uF capacitor suppressed most of the RF better.)

V1: Filament voltages -3.46V and -6.2V (So, 2.74V across, average -4.83V)
Plate 44.53V Grid* -4.98V (making measurement kills signal)
Voltage across T1 primary: .33 VDC (R=620.5 Ohms) implies Ip=.53 mA

V2: Filament voltages -.97V and -6.2V (so, 5.23 across filament, average -3.6V)
Plate 44.86V Grid -6.163V
Voltage across T2 primary: .19 VDC (R=85.7 Ohms) implies Ip=2.24 mA
Signal at grid: .3V pp Signal at plate: .12V pp Amplification factor .4 V/V

V3: Filament as V2 (5.23V, -3.6V average)
Plate 44.39V Grid -6.162V VB=45.06V
Voltage across Tout primary: .645 VDC (R=174.8 Ohms) implies Ip=3.69 mA
Signal at grid: .5V pp Signal at plate: 3V pp Amplification factor 6 V/V

Here's a simplified illustration of the circuit with some of the important values attached:



V1 has a low filament Voltage, which explains why the plate current is only about .5mA. The tube ought to give a signal Voltage gain of a factor of 8 or so, but the plate resistance at that small Ip is about 20K Ω. The load includes the inductance of the transformer T1 primary. At the AF frequency of 400 Hz, that's 10.8KΩ for the inductive impedance plus 620 Ω for the resistance, a total of about 11K Ohms. So, less than half of the potential signal is going to show up at the transformer. The load from the V2 grid and the .001 µF bypass capacitor are both assumed to be negligible. The math is complex and I'm going to guess the output loss due to rp comes to about .4 of the ideal case, so a factor of 3 gain (for AF) for the stage gain. Since we are reading about 3Vpp at the transformer, that implies .5V peak modulation component in the RF at the tuned circuit. (That's fairly close, a quick measurement seems to show.) So, V1 seems to be performing about to expectation.

V2 receives a signal at .3Vpp at the grid. That's about what's on the primary divided by 10, reasonably close to expectation given the 9-1 turns ratio of T1. But, at V2 plate we see only .12 Vpp of signal! That's a Voltage amplification of .25. Well, the transformer being driven has a primary inductance of only 162 mH, equivalent at 400 Hz to an impedance to AC signal ground of just 407 Ohms. At Ip= 2mA, the tube output resistance is about 12KΩ. So, the expected exit loss is about ($Z_L/(Z_L$+rp)) ignoring the complex math difference, about .03. Together with a factor of 8 for the ideal Voltage amplification, we indeed get about .25. So, the tube is performing about to expectation, except, why is Ip only 2 mA, rather than over 3mA as for V3 with the same Q point Voltages? V2 must be relatively low emission compared to V3. The characteristic tables for these CX301A (similar to the 201A) show 2 mA at grid bias of 0 Volts. V2 and V3 are at VG= -6.2V, and about -1V to -6V on the filament, depending on what you point to. If you go by the -6 Volt end, the bias Voltage is about zero. From the plate characteristics, that should only happen with a few Volts of positive grid. A lower rp from having 4mA of plate current would increase the gain about 50%. (Or, maybe V3 isn't a 201A!)

V3 receives on its grid a signal of .5Vpp, about 4 times the value of the V2 output before the 4x step-up transformer. The plate output is 3Vp-p, a factor of 6 larger. With nearly 4mA of plate current we expect an rp of about 9KΩ. The output / speaker transformer is driving an 8Ω speaker and has a turns ratio (estimated from inductance data) of a bit less than 9-1. So, the speaker reflected back through the transformer is about 650Ω. There is also DC resistance of the winding itself, of 178 Ohms. The high inductance of the primary at 400Hz gives about 3.4KΩ, large compared to the resistive component of about 830Ω. So, we would think that the tube gain would be wiped out by the output loss. (That's why the instructions for the CX301A vacuum tube recommend using a power tube instead for the final output.) So, why do we get as much gain as we do? The hint visible in the oscilloscope trace is that there must be some sort of resonance that appears. The waveform is double peaked, which suggests something irregular is appearing in the final stage. That means that one can't expect that boost in normal radio received signals; the output Voltage would typically be lower than the grid Voltage at the plate of V3.

So, V3 is exceeding expectations, thanks apparently to a bit of resonance in the speaker circuit. (The signal generator does not provide choices other than 400 Hz, or I'd have tried that.) Or, possibly, this tube is a specialized power tube instead of being a 201A as assumed.)

The conclusion I reach after the exploration done is that the radio is operating properly. But, it is trying to drive a speaker load that it wasn't designed for, and the two stages of audio amplification with the tubes of that era are simply not enough to give an audible signal in typical radio circumstances. The radio really needs a "horn speaker" designed for efficiency and high impedance. I just don't have one. (Trying to purchase one on eBay is chancy – will it be functional, or not? For that kind of money, I'm not in a hurry to take that gamble.)

Consider the RCA Radiola 17 that provides a different approach to radio design. That radio has three RF amplifiers before detection, the detector is a special tube designed for that purpose with an indirectly heated cathode, so you don't have a variation in filament potential, and hence a sharp cut-off. There are two transformer coupled audio stages after the detector, the last of which uses a specially designed output tube rather than the generic #26. The result is plenty of volume from a high impedance (likely fairly efficient) speaker. That was a product just 3 years later. Radio technology was developing at an amazingly rapid pace. Within 10 or so years AM radio was very good, with superheterodyne receivers including short wave bands.

The regenerative receiver benefits issue:

One of the reasons I was interested in these particular radios, among all the many interesting and even beautiful old radios, was the regenerative detector issue. These Crosley radios are all built around that feature. What does the use of regeneration do to benefit the receiver? I wanted to look for a quantitative answer.

My assumption was that the presence of the tickler coil would have a negligible effect if the tube was unpowered, and the plate circuit open. I had already done some characterization of the tuning inductor and variable capacitor, but I had not looked at bandwidth, the Q of the coil, and how that might be affected by regeneration. A test was devised.

First, center frequencies were measured for both #4 and #5 bands under condition of minimum and maximum capacitance from the tuning capacitor. This was done with the radio unpowered, so it was taken as characteristic in the absence of feedback. Then, for each center frequency, the signal generator frequency was adjusted to find the upper and lower half power (3dB) frequencies, the difference being the bandwidth. The Q is the center frequency divided by that bandwidth. Then the power was turned on, and a similar set of measurements made for the same tuning inductor and tuning capacitor settings. The signal generator was set to 2V p-p with no modulation. As before, it fed the series tuned circuit via a 1MΩ resistor. The measurements were made at the junction between the tuning capacitor and inductor. A probe with a parasitic capacitance measured at 33 pF was used. (This would have a significant effect on the capacitor minimum readings, but a similar effect both with and without power.) The feedback (tickler) coil was as far as it could be away from the tuning inductor. The Table below contains the data.

Tuning:	center freq.	signal p-p	lower -3dB	upper -3dB	Q
#5 (max L), max C	960 KHz	4.0Vpp	940 KHz	983 KHz	22
#5 (max L), min C	1025 KHz	3.9Vpp	1015 KHz	1048 KHz	31
#4 (smaller L), max C	1070 Khz	3.7Vpp	1042 KHz	1097 KHz	19
#4 (smaller L), min C	1140 KHz	3.9Vpp	1120 KHz	1162 KHz	27
#5 (max L), max C	960 KHz	8.4Vpp	948 KHz	970 KHz	44
#5 (max L), min C	1025 KHz	10.4Vpp	1020 KHz	1036 KHz	64
#4 (smaller L), max C	1064 Khz	9.2Vpp	1060 KHz	1078 KHz	59
#4 (smaller L), min C	1140 KHz	11.5Vpp	1128 KHz	1142 KHz	81

The effect of having power to the detector tube, and some energy coupled back to the tuned circuit, was to about double the magnitude of the signal and narrow the band width. (It's also worth noting that if bandwidth is taken into account band #5 almost meets band #4 under feedback conditions; the gap is small but still present.)

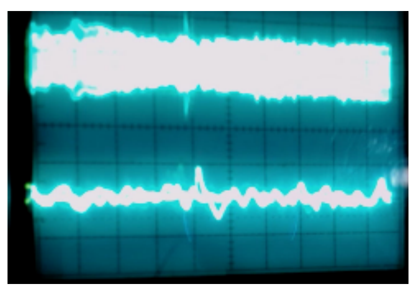
The pulling in of the feedback loop to increase coupling did have some effect, and did throw the radio into oscillation which caused a loud squeal in the speaker in the absence of modulation. This was tried at band #5, maximum C. Just short of oscillation the tuned circuit Voltage reached 11.5Vpp. at 960 KHz, higher than the 8.4V seen earlier. However, just waving one's hand over the radio could throw it into oscillation.

So, the effect of regenerative feedback under relatively "safe" usage typically doubles the signal Voltage over what might have been without feedback, a 6dB gain. Pushing the envelope could approach a factor of three, about 9 dB gain, but with the need to go in and out of feedback to find a suitable operating spot. It may be that manipulation of the detector filament might have allowed the radio to be pushed even further.

In 1924, the complexity of using regenerative feedback may have been less expensive than using another method, such as adding another RF tube. It does allow a high Q suitable for broadcast band with just one tuned circuit. The Radiola uses three, meaning a much more expensive variable 3 ganged capacitor, and incidentally, one that has deficient alignment knocking out the lower end of the broadcast band. The Crosley radio seems to be unable to tune in the lower part of the broadcast band too, because the capacitor-inductor combinations allow going down to only about 1000 KHz, and there seem to be gaps between the bands above that frequency. As electronics became less expensive and new developments came into practice, regenerative detection just wasn't worth the trouble and the complexity of the tuning process, even if one considered regenerative squealing tolerable.

Hearing it Work:

Another attempt was made to scan the spectrum starting with band #5 and working up to the top. Scope probes were left active on the tuning circuit and at the detector output, so the tuning was affected by that additional capacitive load. Three stations were heard. The first two produced insufficient audio for me to understand what was being said, but clearly it was talking. I had to put my ear near the speaker to hear it. It was easier to see the modulated signals on the tuning coil and detector output than it was hear the program. In fact, that was how I found the stations, by looking for indications of action on the scope. The third station was loud enough to hear a few feet from the speaker. It was playing music, and that likely made the station more recognizable. In each case, I created a beat tone with the signal generator then nulled the heterodyne where the signal frequencies matched to get the station frequency. The detector filament knob was key in getting a sufficiently loud signal. If pushed just a bit too far the radio would go into oscillations, and then the filament Voltage needed to be decreased until the oscillations stopped, and another approach made. The image shown is the best I could do to illustrate the scope while listening to the station at 1350 KHz.



Settings:	frequency	program
#4, C at 58	980 KHz	talking
#2, C at 40	1510 KHz	talking
#2, C at 95	1350 KHz	music

Conclusion:

The Radio works! It needs a suitable high efficiency speaker that will give adequate sound. It is effective only over part of the AM band. It's fiddly. It takes a lot of work to find stations. But, it works. From the perspective of 1924, that was an incredible success.

This isn't the end of my involvement with these radios, but for now I need to move on to other things. So, I am concluding the story here for now, and perhaps after editing I'll share it with a few others who may have an interest.

Appendix: Data sheet for the CX-301-A tube (From Cunningham Radio Tubes Manual, pp 22-23)

Cunningham RADIO TUBES

CX-301-A

DETECTOR, AMPLIFIER

The '01-A is a three-electrode storage battery tube for use as a detector and as an amplifier.

CHARACTERISTICS

Filament Voltage (D. C.)		5.0	Volts
Filament Current		0.25	Ampere
Plate Voltage	90	135 *max.*	Volts
Grid Voltage	−4.5	−9	Volts
Plate Current	2.5	3.0	Milliamperes
Plate Resistance	11000	10000	Ohms
Amplification Factor	8	8	
Mutual Conductance	725	800	Micromhos
Grid-Plate Capacitance	8.1		μμf.
Grid-Filament Capacitance	3.1		μμf.
Plate-Filament Capacitance	2.2		μμf.
Maximum Overall Length			4 11/16"
Maximum Diameter			1 13/16"
Bulb (See page 42, Fig. 8)			S-14
Base			Medium 4-Pin

INSTALLATION

The **base** pins of the '01-A fit the standard four-contact socket. The socket should be installed so that the tube will operate in a vertical position. Cushioning of the socket in the detector stage may be desirable if microphonic disturbances are encountered. For socket connections, see page 39, Fig. 1.

The **filament** in the '01-A is intended for operation from a 6-volt storage battery. A fixed or variable resistor of suitable value is required to reduce the battery voltage to 5.0 volts across the filament terminals at the socket. At this voltage, the most satisfactory operating performance will be obtained.

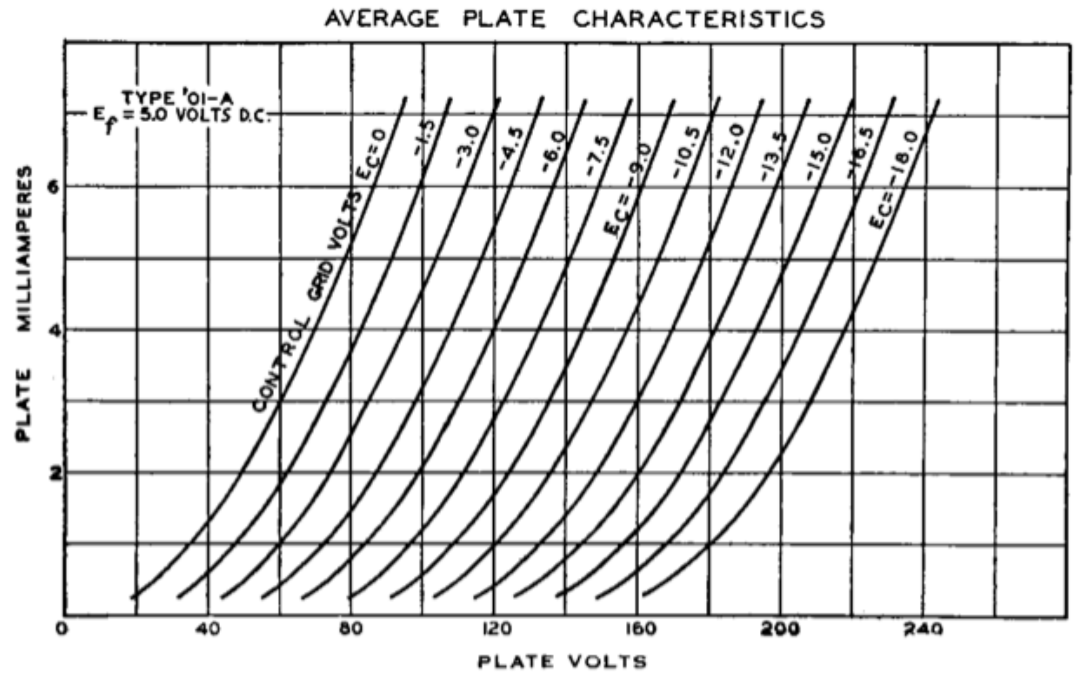
APPLICATION

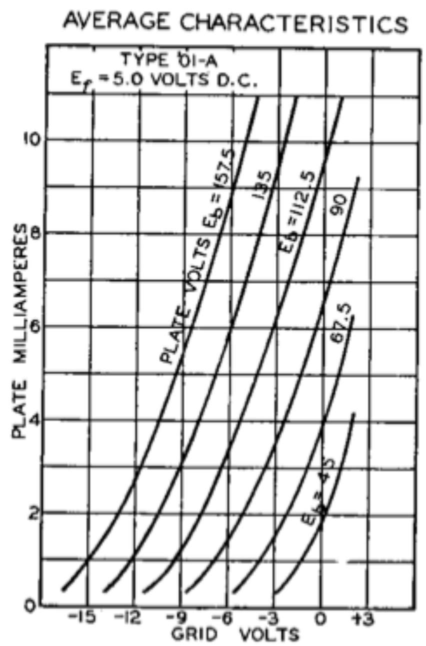
As a **detector**, the '01-A may be operated either with grid leak and condenser or with grid bias. The recommended plate voltage for the former method is 45 volts. A grid leak of from 1 to 5 megohms used with a grid condenser of 0.00025 μf. is suitable. The grid circuit return should be connected to the positive filament terminal. For grid bias detection, plate voltages up to the maximum value of 135 volts may be used with the corresponding negative grid bias voltage (13.5 volts approximately).

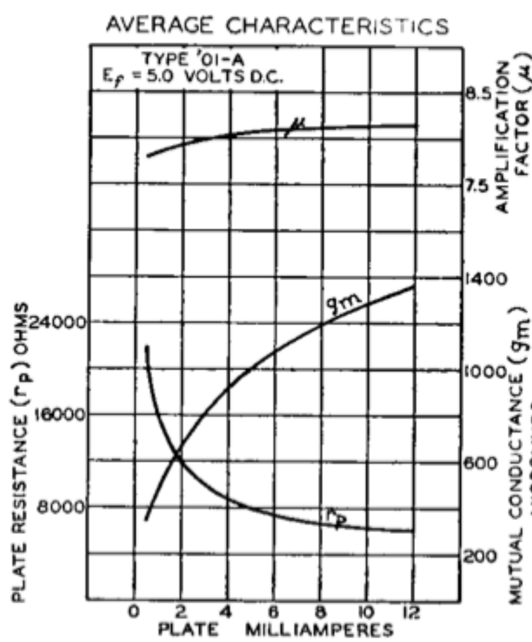
As an **amplifier**, the '01-A is applicable to the audio- or the radio-frequency stages of a receiver. Plate voltages and the corresponding grid voltages for audio amplifier service should be determined from the tabulated characteristics and the curves in order to obtain optimum performance and freedom from distortion. The higher plate voltages will be found advantageous under conditions where the impressed signal is large or where maximum voltage output is desired.

When the '01-A is used as a radio-frequency amplifier, little is gained from the use of plate voltages exceeding 90 volts. The '01-A is well adapted for use as an interstage audio-frequency amplifier but a power output tube is recommended for the final audio stage.

Volume control of the receiver may be accomplished by variation of either the grid bias or the plate voltage applied to the radio-frequency stages.







(The 201A Vacuum tube is similar, and was replaced by the 301A when it came out.)