The Bendix RA-1B aircraft radio receiver

Ulrich Fierz HB9AIK

The RA-1B receiver by Bendix Aviation Corp. was designed as a LF/MF/HF receiver to serve in aircraft. It was to provide long-range HF communications (telegraphy and telephony) and direction finding (NDBs or broadcast stations). As such, it is similar in concept to the well-known BC-348 series. The frequency ranges and other information can be seen from the nameplate on the front panel in **Figure 1**. There were variants, differing slightly in frequency range called RA-1I and RA-1J. The receiver can be operated locally or remotely by a MR-1B/I/J control unit, using Bowden cables and electrical interconnections. Audio output was for headsets only. The dynamotor power supply is not integrated as it is in the BC-348 but is a separate unit: MP-5B for 12/14 VDC or MP5A24 for 24/28 VDC. For the DF applications, Bendix supplied special units with a ring antenna and an integrated amplifier. The receiver was first offered in 1941 and continued to be manufactured at least until 1946 (as shown on the label). Known applications include the long-range Douglas C-54/DC-4 aircraft during WWII and, after the war, somewhat depending on airlines, *e.g.* the DC-4, the Boeing Stratocruiser or the Consolidated Catalina commercial airliners. The author's unit was used by SWISSAIR in their DC-4 planes (as shown by a painted-over decal that included an inventory number). Actual production numbers appear to be unknown.

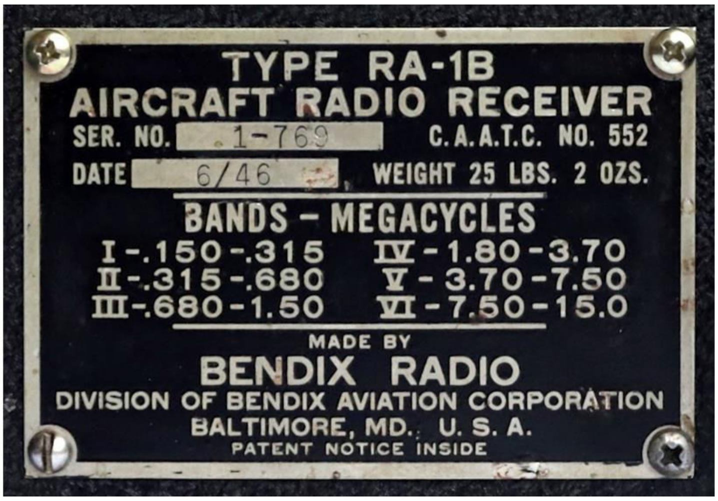

Figure 1. RA-1B nameplate

Description

The RA-1B receiver is a superhet with RF amplifier (6K7G), mixer (6L7G), separate heterodyne oscillator (6K7G), two 1630 kHz IF amplifier stages (6K7G), separate BFO (6K7G), detector and AF amplifier (6R7G) and audio power amplifier (6K6G). RF amplifier, mixer and first IF amplifier are controlled by AGC and RF gain control. Octal glass valves are used throughout and, except for the 6K6G, all with an aluminum shield. The circuit is fairly conventional and described in detail in the comprehensive 1941 manual. Two notes, however, appear to be useful:

- In 1944, an important modification to the AGC design was published by Bendix and was incorporated in all later units. The author's receiver was made in this way. AGC is now rectified separately and delayed by applying a positive bias to the cathode of the 6R7G. The audio recovery path remains without bias and overall AGC performance is improved. AGC now remains always on and the AGC OFF switch just activates the RF gain potentiometer.
- The volume control is not on the input to the AF amplifier, the audio path always having constant gain. Potentiometers in the radio and in the control unit follow the output transformer and regulate the level to the headphones. AF and RF control pots are further ganged on the same axis. This arrangement, is not very convenient for general use and has resulted in most radios being modified in their 'second life', often using a higher gain 6SQ7GT with a low-level volume control.

The mechanical design of the radio is solid and has stood 'the test of time' well. The chassis is made of heavy-gauge welded aluminum and carries all important elements. The front panel of the same material is bolted to the chassis and carries the connectors and operator controls. The RF coils and band switches are in screened boxes, all switches, valve sockets, IF filters, *etc*. use ceramic insulation material. Phenolic resin is used only on the turret boards. Tuning and band switching are *via* worm gears driven from knobs with integrated gears for the Bowden cables on the front panel. The tuning capacitor has a back-lash compensated drive wheel on the worm. The following **Figures 2 and 3** show the chassis layout and the front panel of the refurbished radio.

The author's RA-1B radio

Back in 1963, this ex-SWISSAIR radio sat in the window of an electronics hobby shop and caught my attention. No accessories, just the receiver, but then a desirable improvement over my radios. I could not resist it… They also had a surplus stabilised power supply (with valves of course) and later I found a vibrator supply for 6 VDC.

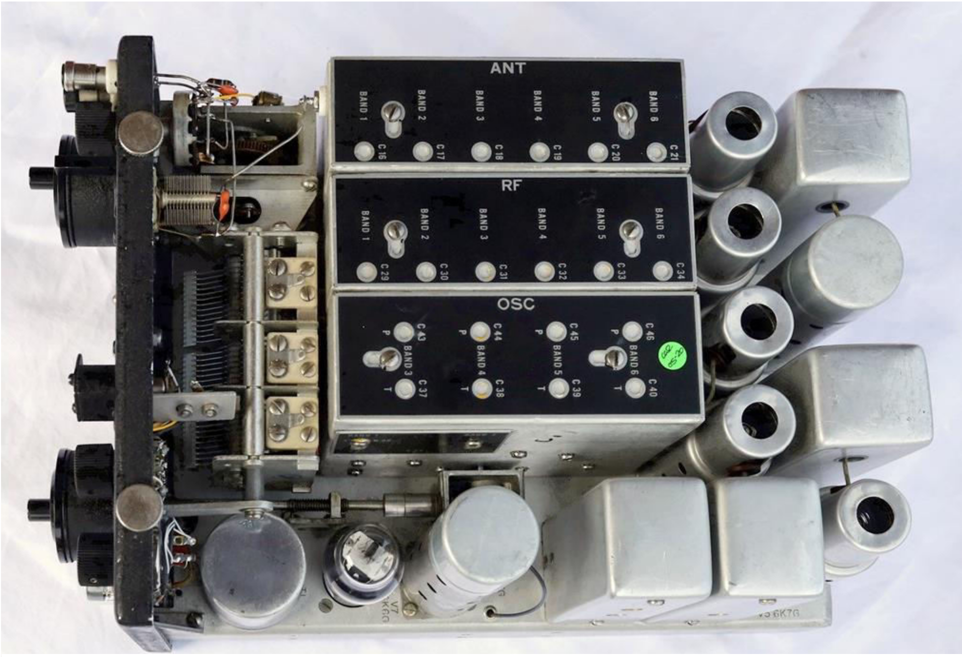

Figure 2. RA-1B: above-chassis view of the refurbished radio

After a few years, the receiver was retired and spent a long time in storage – until now as a matter of fact. Then an article appeared in *Signal* and nostalgia took over…

Bringing the receiver back to life.

Inspection

Taking the radio from storage, it was in a good condition on the outside, no visible damage, the controls turned and only light dust was present. Removing the case, showed a somewhat different picture. While the radio was in good shape when I got it and my earlier work was not bad, the bathtub capacitors caused a deplorable mess in the years since. The chassis and the central tag board were covered in an oil film, some brass hardware and blank wires showed green corrosion products and the wax on resistors was partially dissolved. Fortunately, all mechanical parts and the filter cans were clean and unaffected.

Assessment

Obviously all the bathtubs had to go, especially those under the main tag board. And the dirty main tag board itself? After a good look at it, considering that to get at the bathtubs it had to be removed anyway, it appeared better to remove everything, clean and rebuild it. The four small turret-boards around the chassis edge were better, but looking at replacing the capacitors around them, the same treatment appeared reasonable.

The cable-form was still acceptable and could be left in place, with the unsoldered ends redone, that should work out satisfactorily. New wiring would replace the various short bits removed from the bathtubs and tag boards.

My old modifications needed to be removed, heaters set again to 12/24 V, the RF amplifier back to a 6K7G, the small audio filter and the tuning indicator taken out and the AF amplifier rebuilt. The old audio transformer was still available, but should the inconvenient gain control design really be restored? Is the dual potentiometer still serviceable (it was not), and what about the tuning indicator? (another was installed). Should the remote control connector and switch be reinstalled (the switch was still viable but the correct remote connector could not be found).

Then remained the question of the power supply. Should this be a historically correct dynamotor supply or simply a new unit (a suitable dynamotor supply was found)?

Basic rebuild

My old modifications, the tag boards, the bathtubs, composition resistors and short wires which were not part of the cable-form were removed and scrapped. The three RF boxes and valves, including shields, were also

Figure 3. RA-1B front panel (refurbished radio)

The next step was making it operational, based on a white on a black photocopy of the circuit diagram only. I was not into collecting then, but a somewhat experienced hobbyist. Like many others, I rewired the heaters for 6.3 V, added a volume control and a 6SQ7GT/6V6GT audio amplifier configuration. A surplus audio transformer was used to drive a low-impedance speaker. The result at the time was excellent; it is a fine receiver and many broadcast stations could be logged and easily be found again. It was even operated in the field and taken on holidays.

Operating experience showed the need for a simple AF low-pass filter (the IF is not very narrow) and a tuning indicator. The latter was an EM87 magic eye, installed in place of the remote connector socket. Later I changed the RF amplifier to an EF89, but more based on hearsay than actual know-how.

removed to simplify cleaning. The IF Filters, cable-form, connectors, valve sockets, the tuning capacitor, switches and all gears were left in place. Not removed were also all the mica capacitors inside the filters and RF boxes. Cleaning was then performed mostly using WL cleaning fluid and a soft cloth, slowly in sections.

For the following description refer to **Figures 4 and 5** and the circuit diagrams in **Figures 6 and 10**.

The first step was rewiring of the heater circuit (**Table 1**). The old wire-wound resistors could be found but, due to the change in audio preamplifier valve and the addition of the tuning indicator, a new arrangement had to be found. While 24 VDC is used here, the centre is at 12 VDC and allows the optional wiring for this voltage as in the original. The equalizing resistors were put on a new tag board behind the input connector (which also carries components for the new audio and indicator circuits), but the voltage selection is still done *via* jumpers on the original tag board.

Replacing the three 100 nF bathtubs was done using 150 nF/630 V radial film capacitors and this required new terminal strips to be installed in the old mounting holes. To save space, low-voltage cathode bypass was done with 100 nF/25 V ceramic components. For the 6K6G cathode and the positive bias bypass, solid tantalum capacitors were used.

Rebuilding the cleaned turret-boards, carbon film resistors, high-value metal film and a few wire-wound power units were used. As the old values were not E12 standard, the next higher value was selected as far as possible. Only a small number of adjustments were needed later on test.

After installing the boards and the RF amplifier valve socket, the cable-form was reconnected, each end carefully terminated and a ~¼-inch shrink-sleeve applied. For the remaining wires, PTFE-insulated wire was used, if possible with the correct colour coding.

Branch 1		*optional*	Branch 2			
	25.2V IN	GND		25.2V IN		25.2V IN
V4 6K7G	.3A		**V5** 6K7G	.3A	**DL1** #47	.15A
V1 6K7G	.3A		**V8** 6K7G	.3A	**R43** >1W	47R//220R
	(● - - - -	12.6V IN	- - - - - - - - - - - - -	● - - - - - - - -	- - - - - - - -	●)
V3 6L7G	.3A		**V6** 6B8G	.3A	**V9** 6AL7GT	.15A
				●----------------	----------------	●
V2 6K7G	.3A		**V7** 6K6G	.4A	**R44** >0.5W	150R
	GND	GND		GND		GND

(● - - - ●) *optional link* ●--------● *needed balance link*

Table 1. Heater configuration

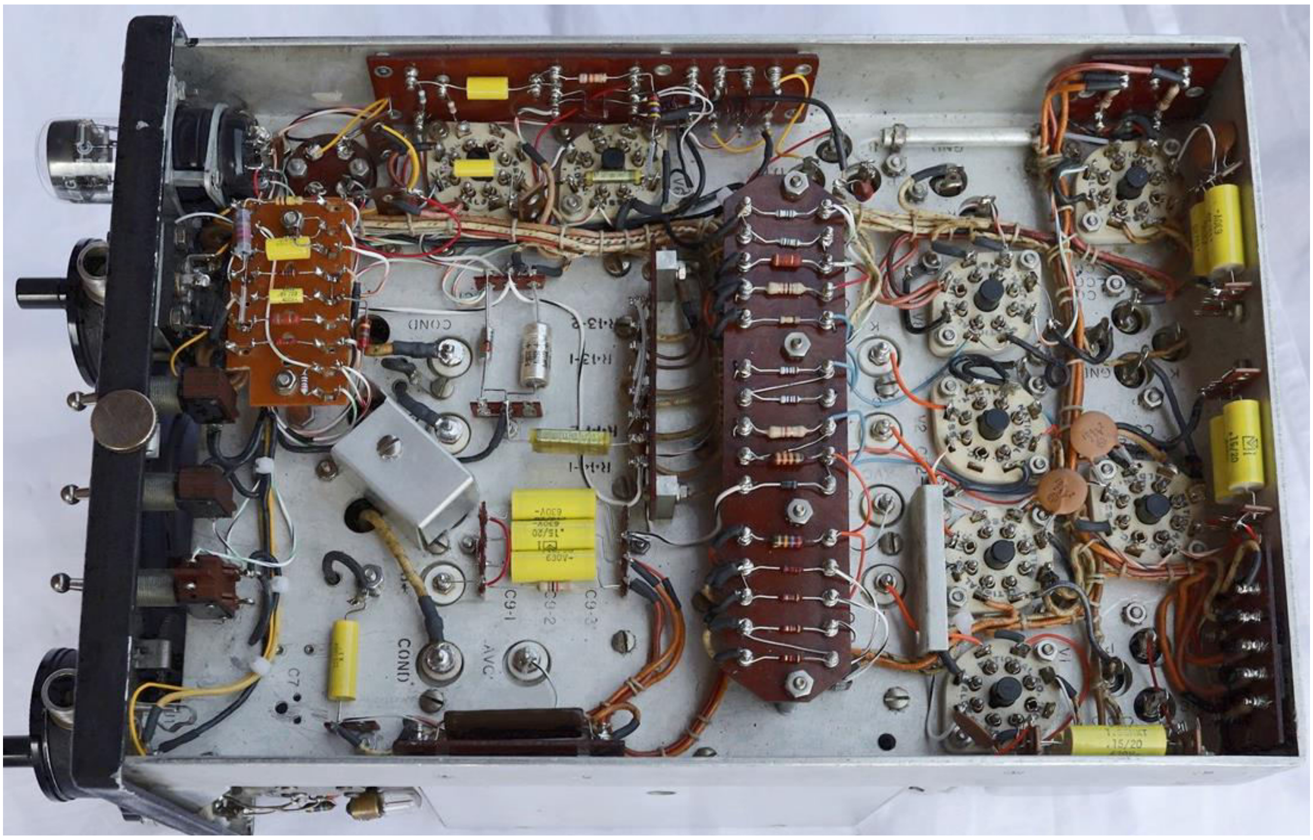

Figure 4. RA-1B: Under-chassis view of the refurbished radio

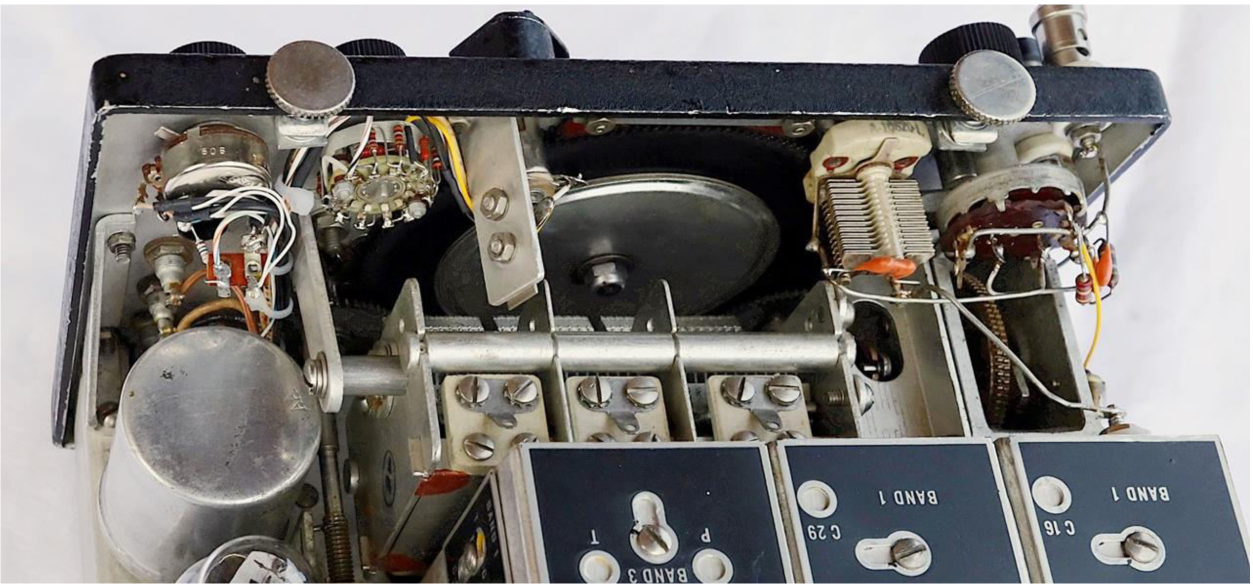

Figure.5. RA-1B: front panel, rear side view of the refurbished radio

dB	R test	ΔR E12	ΣR	dB	R test	ΔR E12	ΣR
0	0			-60	1'743	560	1'750
-10	212	220	220	-70	2'420	680	2'430
-20	404	180	400	-80	3'190	820	3'250
-30	540	180	580	-90	4'060	820	4'070
-40	780	220	800	-100	5'150	1'200	5'270
-50	1'204	390	1'190	-110	not meas.	1'500	6'770

Table 2. RF gain resistor chain. 'R test' is the target value in Ω for a given attenuation. ΔR is the step-wise resistor using E12 values and ΣR is the resulting resistance to be compared with 'R test'

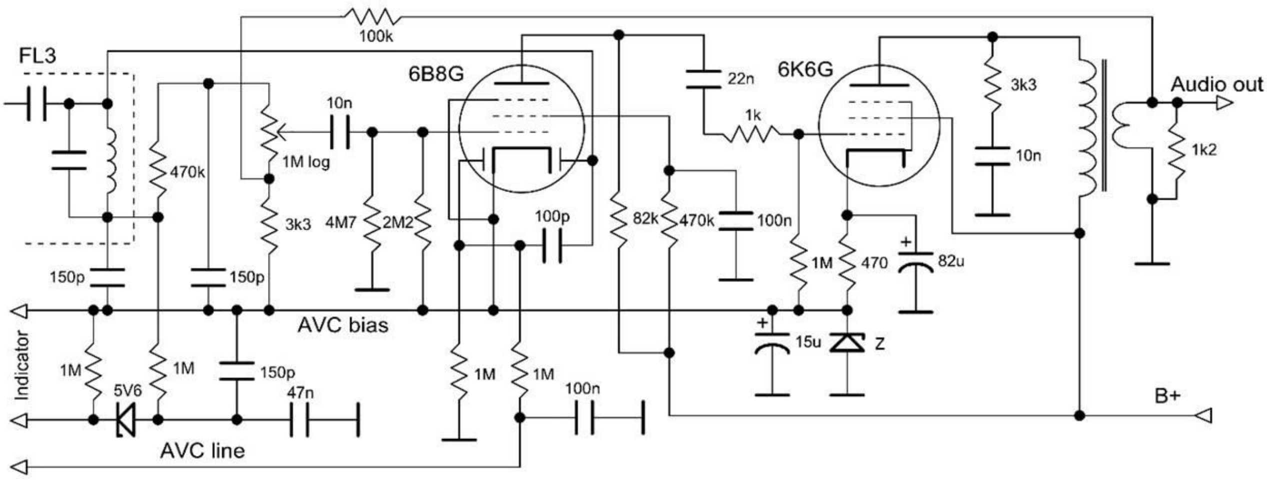

Figure 6. New detector and audio circuit

RF and IF sections

The RF/IF sections of the radio were rebuilt exactly as *per* 1944 circuit diagram. Exceptions are R10 which was replaced by an 82-volt zener diode (for stability of the oscillator), R50 with a Zener diode for positive bias generation, a 56 Ω termination on the DF input (the receiver will be fed from a distribution amplifier) and a new RF-gain control. The RF potentiometer with its special non-linear curve failed, so a 12-position make-before-break switch was used instead. A resistor chain was implemented, lowering the gain in approximately 10 dB steps. The values were determined on test by constant audio output with AGC off. The step-size varies somewhat with the band selected and actual valve characteristics. The switch is visible in **Figure 5**, in place of the remote switch and the chain, which shows the resistor chain and the actual values, together with the gain profile is given in **Table 2**.

Audio amplifier

The audio section was redesigned to include a low-level volume control and negative feedback. More gain is thus needed in the preamplifier and, as a G-style valve with shield was required and I did not have a 6Q7G, a pentode circuit with a 6B8G was selected. The detector circuit for AGC remained unchanged, but the values of the resistors in the audio path were adapted to the 1 MΩ audio taper potentiometer used. Negative feedback is from the secondary of the audio transformer to the raised lower end of the volume control.

To obtain optimum output power from the 6K6G, the anode current was increased. The output impedance was then found to be approximately 200 Ω. To stop oscillations (~50 kHz) when driving the speaker, C83 was removed and a new RC (33 kΩ+10nF) combination in the anode of the 6K6G added.

To drive the speaker, a 600 Ω:8 Ω transformer was installed in the power supply, unfortunately before the load measurements were taken. As the 6K6G is a low-power audio valve, a proper match to the speaker is needed. With the selected 8 Ω speaker from a military LS-166 unit, high audio volume was only achieved after adding a 4 Ω:8 Ω step-up transformer.

The circuit diagram of the audio section is shown in **Figure 6**.

Tuning indicator

The old EM87 sticking out was always somewhat vulnerable and too ‘modern’. Initial thoughts leaned towards a 1629 indicator which was used in the ARC-5 command sets but, in the end, a shorter component was selected: the 6AL7GT. This is an indicator for AM/FM receivers with three rectangular sectors, used here with just one input. While not as attractive as the round magic eyes, it is compact and of the correct diameter to fit in the space of the remote connector (**Figure 3**, lower right-hand corner).

The tuning indicator is driven directly from the audio demodulator diode, *i.e.* without the positive AGC bias. This allows better tuning of weak signals but has the disadvantage that BFO leakage is visible as well.

The circuit diagram of the connection to the indicator is shown in **Figure 6**.

Front-panel wiring

The wires leading to the remote switch and connector were removed rather than just being insulated. An octal socket for the tuning indicator was installed behind the remote connector cut-out. It is fixed with a clamp as it has to be rotatable to align the display square of the 6AL7GT. The headphone jack was replaced by a unit with a switch, to mute the speaker when using headphones. The AGC OFF switch now again disables AGC with the RF gain control always active.

As a result of these changes, a new tag-board was installed behind the connectors – mostly using the space formerly occupied by C91 – to accommodate the new components needed. The front panel wiring was reorganised and complemented to include the new interconnections using PTFE-insulated and shielded wires.

Tests and alignment

For testing of the completed receiver, a low- and a high-voltage laboratory power supply were used. This allowed proper voltage checks against the values in the manual and stable conditions for the alignment. Audio output was terminated with a 180 Ω resistor and measured with a HP333A distortion analyser while being checked on an oscilloscope. RF/IF signals were produced using an AFG-2125 synthesized function generator followed by an HP step attenuator. DC voltages were measured with a HP410C and a Philips PM 2525 digital meter. Operation of the RF gain switch and determining the resistor values with AGC off had to be done using an HP8640B generator as the broadband noise produced by the function generator did not allow tests at the noise threshold or to determine sensitivity of the receiver.

A few resistor changes were found necessary after checking voltages indicated in the manual. The amount of negative feedback was determined experimentally, obtaining sufficient audio with an input signal at the noise threshold. AGC bias was selected to be lower than intended by the 1944 modification whose value might have been selected to better reduce unwanted AGC action by BFO leakage.

Dynamotor power supply

Looking through dynamotors in stock and thinking of building a supply, the auction site was also consulted for BENDIX dynamotors. I did not find the original power supply for the radio, but a unit reasonably close in vintage, size, appearance and capabilities: DA-184C made for the ARN-14A system which provides ample B+ (at about 80 mA), was ordered and shipped from the US.

The unit includes the necessary start relay, B+ choke and filter capacitors as well as various noise-suppression components.

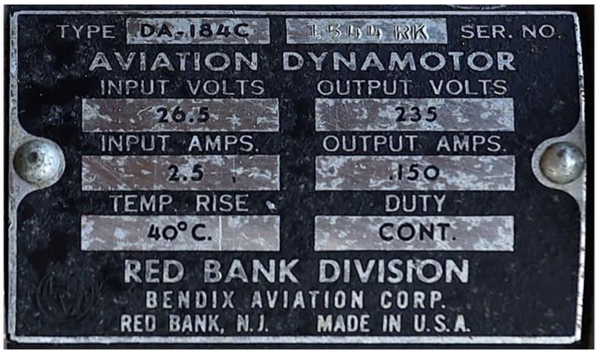

Figure 7. Dynamotor nameplate

The two B+ filter electrolytic capacitors C602 and C605 were within a box and each had a heater winding sleeve that was controlled by a +10°C thermostat. Quite unique, and I have not encountered this before.

The paint on the outside was rough, but the unit was very nice inside and appeared to come out of a refurbishment service without any use afterwards.

To bring it back to life, the bearings were serviced and the electrolytic and paper capacitors replaced. As there was no plug available for the round multipole socket J601, a MIL-5015 socket that fitted the existing mechanical arrangements and for which I had a cable plug, was installed.

The B+ filter capacitor is now a dual unit and the resulting spare hole is occupied by the 600 Ω:8 Ω audio transformer. The outside was cleaned and the paint slightly touched up. The refurbished power supply is shown in **Figures 8 and 9**; the extended bracket is needed for the shock-mount used.

Figure 8. Dynamotor, topside (refurbished unit)

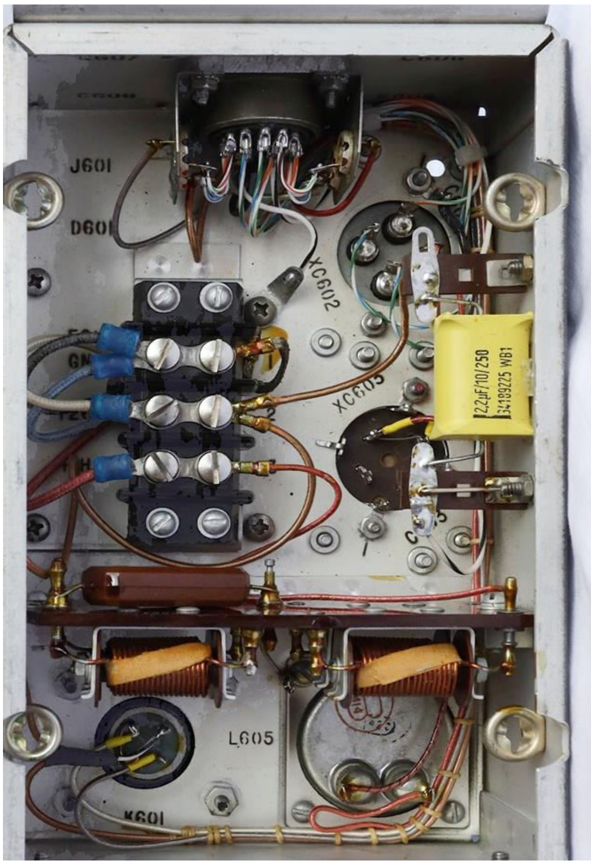

Figure 9. Dynamotor, underside (refurbished unit)

The unit was then tested using laboratory load resistors and an 8-amp regulated power supply and everything worked fine. B+ tends to be on the high side with the lower load drawn by this radio and the required input voltage should indeed be 26.5 VDC and not 28 VDC for the correct output voltage on load. This is fine, as the heaters are connected directly across the input voltage too. The regulated supply was able to start the dynamotor, the 8 A current limit proving sufficient.

Unwanted electrical noise generated by the unit and propagated through the cabling was not measured as the setup was intended as a working display only.

There is no circuit diagram of the dynamotor power supply, but **Figure 9** shows the components inside the chassis. In the lower section are the relay K601 and the B+ choke L605. On the tag board above are the RF filter components for the DC input and B+. In the top section C605 is the dual electrolytic and in the place of C602 is the speaker audio transformer. Note the feedthrough capacitors on the wires going to the connector.

Display plinth and complete system

In order to be able to display and demonstrate the receiver, an aluminium plinth was constructed to allow proper grounding of the components – similar to an aircraft installation (**Figure 11**).

The receiver was put on shock mounts that fit into the mounting rails of the receiver and the dynamotor was put on a suitable aircraft mount. All cables were made up using selected gauge PTFE-insulated wires for the required functions which were pulled into a silicone sleeve. As experience showed later, it would have been better also to include a shield braid to further reduce EMI.

The speaker is an old LS-166 that was repainted black and bolted to the plinth without the rear cover.

The +28 VDC power input is filtered by a high-current 2 mH choke and a large 14,000 µF computer-grade capacitor. A series resistor consisting of three 2.7 Ω resistors in parallel reduces the input voltage to approximately 26.5 V and, at the same time, limits the inrush current into the large capacitor. **Figure 10** shows the layout of the plinth. The choke and input resistor are behind the receiver.

On the air

Operating the receiver here in my museum using the antenna distribution in the shack, reception of broadcast stations (not so many these days) was good and audio quality excellent. The latter was helped not only by the feedback arrangement but also by the not so narrow IF, which would probably cause problems receiving CW. Stability after warm-up was very good as it should be. The new RF gain reduction arrangement for very strong stations (*e.g.* Chinese, Romanian in the 31-metre and 25-metre bands) showed good steps and smooth gain reduction. Performance at frequencies below about 4 MHz could not be tested due to the heavy electrical noise present in our area. Nice to have my old receiver back in operation – no matter if it is only for demonstration purposes

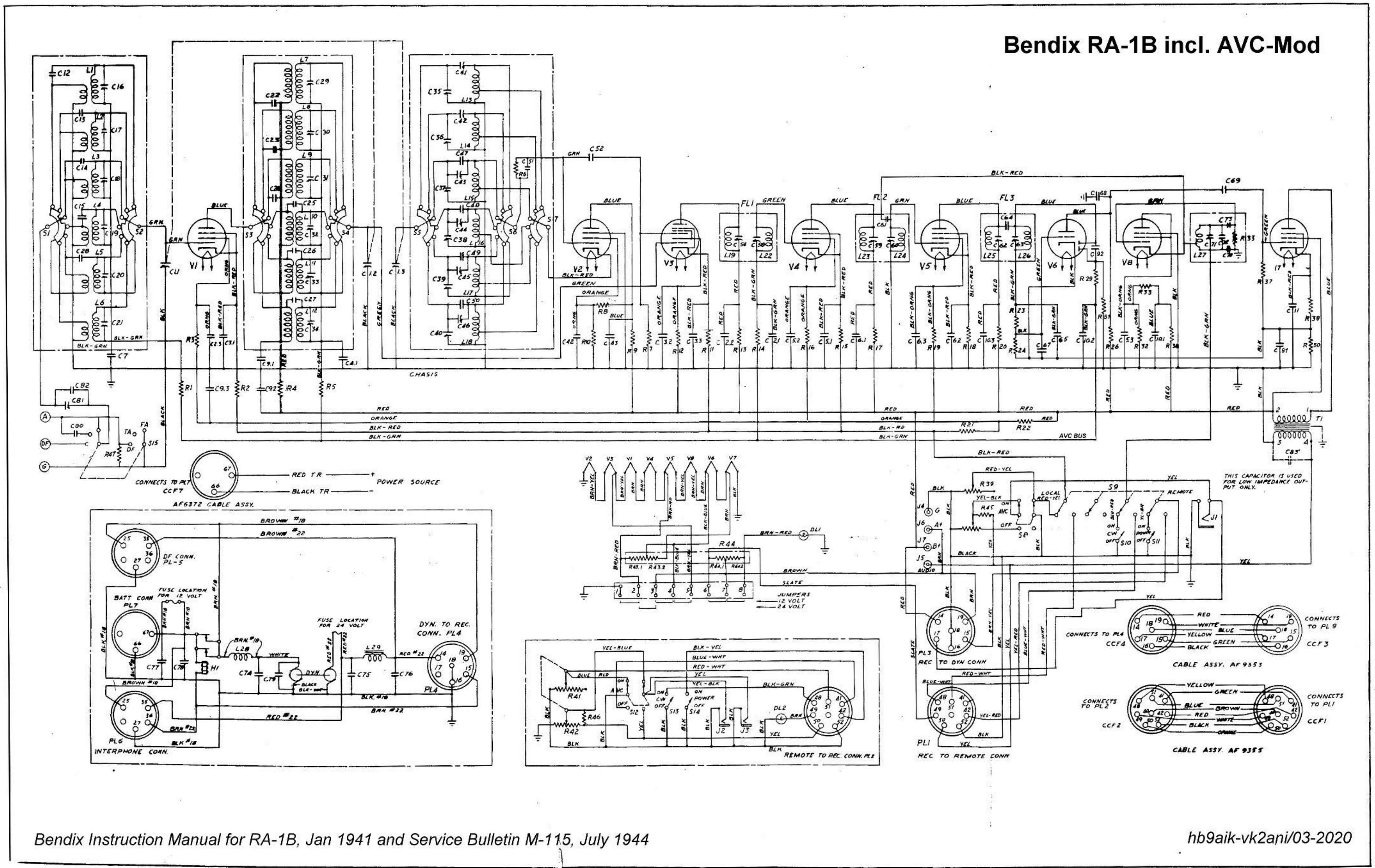

Figure 10. RA-1B original circuit diagram, but including the 1944 AGC modification but not including new component values or details as in Figure 6.

Figure 11. Layout of the RA-1B on an aluminium plinth for demonstration

Extract

Signal

The Journal of the Vintage and Military Amateur Radio Society

Issue 56: August 2020

Contents