

**W8UM STATION EQUIPMENT DOCUMENTATION
AMP-HF-SB-220**

**Equipment: Heathkit SB-220 HF Amplifier
Scope: Description, Operation, History**

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INTRODUCTION:

Please read this entire document once before using the SB-220 for the first time and make sure that you understand all of the procedures. For more information on operation, theory, and servicing, please see the Heathkit SB-220 factory manual and related notes in the W8UM equipment document files.

DESCRIPTION:

The Heathkit SB-220 is a vacuum tube triode-based radio-frequency (RF) linear amplifier for the 80m through 10m (3.5 MHz through 29.7 MHz) amateur radio bands. The amplifier requires careful operation to ensure its safe use. Each time the amplifier is used, it must be properly tuned using the front-panel controls. **Using this amplifier without proper training will result in damage to the amplifier and other W8UM station components.**

The amplifier has two power settings—CW/TUNE (low power) and SSB (high power). It is rated for a DC input power of 1 kW in the CW/TUNE position or 2 kW peak envelope power (PEP) in the SSB position. The amplifier nominally gives 550-650 W of useful output power on CW and 1000-1100 W of useful output power on SSB, at frequencies up to about 21.5 MHz. Above 21.5 MHz, power output will be 400-500 W (CW/TUNE) and 750-900 W (SSB). On high duty cycle modes such as CW, RTTY, and PSK, the low power setting must always be used. **The high power setting should only be used for SSB and only when absolutely necessary**—the 3 dB increase (600 W versus 1200 W) in transmitted signal level in the high power setting results in increased strain on the amplifier tubes, power supply, and output network components, as well as the rest of the system (balun, antenna tuner, etc.) While 3 dB may seem like a lot, it is only “just perceptible” to a human and causes an increase of only 1/2 of an S-unit at the receive-end.

The amplifier’s power supply can be wired for either a 120 VAC or 220 VAC line voltage. If wired for 120 VAC, the amplifier must be powered by a dedicated 120 VAC circuit rated for 20 A. Also note that the amplifier requires at least 6 inches of space above its cabinet to ensure proper cooling.

OPERATION:

Equipment Controls and Warnings

It is assumed that the SB-220 is properly connected to the rest of the W8UM station equipment (HF transceiver, antenna tuner or switch, etc.) If it is not, please refer to the SB-220 factory manual and notes in the W8UM file. **Incorrect installation could seriously damage other equipment or the user!**

The SB-220 has the following front panel indicators and controls:

There are two front-panel meters. The first displays plate current at all times. The second monitors either grid current, relative output power, or plate power supply voltage depending on the setting of the meter control.

Control	Settings	Description
(power)	ON, OFF	Turns the amplifier power supply on and off
(output level)	CW/TUNE, SSB	Sets the amplifier power level by changing the power supply transformer voltage
Band	80, 40, 20, 15, 10	Sets the frequency band of operation
Tune	80, 40, 20, 15, 10 (roughly indicated)	Tunes the tube plate-side of the amplifier's Pi output matching network
Load	0 to 10	Tunes the load-side of the amplifier's Pi output matching network
Sensitivity		Sets the sensitivity of the relative output power meter
Grid-Rel Power-HV	Grid, Relative Power, High Voltage (HV)	Selects the read quantity of the multi-meter.

WARNINGS:

- **Never change the rotary BAND switch position while the amplifier is in transmit mode**
- **Never change the CW/TUNE-SSB rocker switch position while the amplifier is in transmit mode**
- **Never turn the amplifier on without checking that:**
 - **The exciter RF input and relay cables are properly attached**
 - **The amplifier RF output is connected to a 50 Ohm load, resonant antenna, or matching network**
- **Do not use the SB-220 on AM or FM modes—it is not designed for these modes, and using them will significantly exceed the amplifier’s ratings and surely cause excessive damage.**

Initial Settings

- Check that the exciter (usually an HF transceiver) is turned on and set to the desired frequency.
- With the amplifier turned off (power: OFF), and using minimum exciter power (10 W should suffice) check that the antenna VSWR is under 1.5. If it is not, use an antenna tuner (rated at 1200 W PEP or higher) to bring the VSWR under 1.5.
- Set the HF transceiver/exciter output power and mic gain to their minimum settings.
- Set the SB-220 controls as follows:

Control	Setting
(on/off)	OFF
(power level)	CW/TUNE
Band	Desired band*
Load	Mid-mark for desired band
Tune	“2” for 80m and 40m, “4” for other bands
Meter	High voltage

* For the 17m band, use the “15m” position. Use of the amplifier on 30m and 12m is not recommended due to poor input VSWR (the amplifier was not designed for these bands.)

(See next page for Steps of Operation.)

Steps of Operation

NOTE: You must follow these steps whenever you **(1) change carrier frequency** by more than a roughly 1 percent (roughly 30 kHz on 80m, 60 kHz on 40m, 100-200 kHz on higher bands) or **(2) change the input (exciter) drive power level**.

1. Turn the SB-220 on by setting the (power) switch to the “ON” position.

Observe: The cooling fan should be heard and air flow should be felt above the amplifier cabinet. The plate current meter should indicate 0 mA and the multi-meter should indicate 2.4 kV. The 3-500Z tube filaments (visible through the cabinet top) should be glowing white. **If these indications are not present, other noises occur, or smoke appears, turn the amplifier OFF immediately and have the amplifier serviced.**

2. If an external power meter (stand-alone or integrated with the antenna tuner) is not inline, set the Meter switch to “Relative Power”.
3. Key the exciter (using CW or the “tune” setting).

Observe: The amplifier’s transmit/receive relay should make a “click” sound, the plate current should rise to 90-100 mA, and the high voltage reading should drop slightly (to 2.3 kV or so).

4. Slowly increase exciter power control until the plate current increase to 300 mA.
5. Tune the “TUNE” control for maximum output power.
6. Tune the “LOAD” control for maximum output power.
7. Turn the Meter control to “Grid” and check that the grid current does not exceed 200 mA.
8. Slowly increase exciter output power until plate current reads 400 mA, while tuning the “TUNE” and “LOAD” controls for maximum output power (steps 10 through 12).

Observe: With 400 mA of plate current, the output power should be 500 to 600 W (400 W on 10m) and grid current should be under 150 mA.

9. Un-key the exciter.

The amplifier is now set up for operation for 1 kW input power in any mode at the **present frequency and exciter power setting**.

(See the following page for high power operation.)

Steps of Operation, continued

For use in the high power mode (**for SSB only**), follow steps 1 through 9, then follow these additional steps:

10. Make sure that the exciter is un-keyed and that the amplifier has switched back to receive mode (plate current must drop to zero).
11. Switch the output level rocker switch to “SSB”.
12. Turn the “LOAD” control clockwise by 1 mark.
13. Key the exciter. (The SB-220 high voltage should now read near 2.9 kV and plate current around 140 mA.)

The next steps should be done as quickly as possible, usually in under 10 seconds.

14. Slowly increase the exciter output power level until the plate current reads 500 mA.
15. Adjust the “TUNE” control for maximum output power.
16. Adjust the “LOAD” control for maximum output power.
17. Check that the grid current does not exceed 270 mA. If it does, quickly reduce the exciter power level.
18. Continue increasing exciter power and repeat steps 15 through 17 until the maximum output power is achieved at a plate current of 600 mA. With 600 mA of plate current, the amplifier should have an output power of 1100 to 1200 W with 250 mA of grid current (750-900 W on 10m).
19. Un-key the exciter.
20. Advance the “LOAD” control by 1/2 mark. (This ensures that the amplifier will be properly loaded on modulation peaks and reduces the possibility of high voltage transients and arcs in the output network.)

The amplifier is now set up for operation at its highest power setting, for use only in SSB, at the present exciter power setting. **Keep the exciter power level at the current setting**, adjust microphone gain per exciter instructions, and otherwise operate normally.

Additional Notes on Operation

Stand-By

The SB-220 does not have a “stand by” mode, where the amplifier is taken off-line but remains powered. This is because the 3-500Z tubes are “instant on” devices. To operate at lower power (exciter only) just turn the SB-220 amplifier power switch to “OFF”. To put the amplifier back in-line, just turn it back to “ON”—re-tuning is not necessary unless carrier frequency has changed by more than 1 percent or the exciter power level has changed.

Tuning

When tuning the amplifier you must juggle exciter power, amplifier “TUNE” and “LOAD” controls, and keep an eye on several parameters (plate and grid current and output power). Here are some main points to keep in mind: keep these main points in mind:

Always tune the “TUNE” and “LOAD” controls for maximum power output as seen on the power meter at the output of the amplifier (or the SB-220’s internal relative power meter).

Watch for excessive grid current. Grid current that is too high (higher than 150 mA for the CW/TUNE setting or higher than 250 mA for SSB setting) is an indication that the “LOAD” control is not advanced far enough—i.e. the amplifier is too lightly loaded.

Tune as quickly as possible. When the amplifier is not tuned properly, the tube plates are dissipating more than their rated power, causing reduced tube life. It becomes easier once you do it a few times! It should take an experienced operator only 5 seconds to tune the SB-220 on a new frequency and/or power level.

Operation above 15m (21 MHz)

Above 15m, the amplifier is less efficient, the tubes and output network components dissipate considerably more power (in the form of heat) while output power is reduced by 25% or more. Tuning also becomes more sensitive. For these reasons and the fact that much less power is usually needed on 10m when propagation is good, it is advised that the SB-220 be used on 10m when absolutely needed. (The SB-220 is not designed for use on 12m and its high input VSWR will cause additional problems, so use on 12m is also not advised.)

HISTORY:

This amplifier was donated to the U-M ARC by Mr. Joe Firlit WA8RTL, a Michigan (EE) alumnus, in the summer of 2004. The amplifier has been serviced by the club members for its reliable operation at W8UM.

Work performed as of 12/27/06:

1. Installed Harbach Electronics power supply capacitor bank (improved capacitors and voltage equalizing resistors)
2. Installed Harbach Electronics diode/metering circuit board (improved materials and devices, meter protection)
3. Installed Harbach Electronics “soft start” circuit board (inrush current limiting protection for power supply and tube filaments)
4. Installed Harbach Electronics “soft key” circuit board (low voltage keying interface to allow relay operation with solid-state transceivers)
5. Installed Harbach Electronics larger capacity cooling fan assembly (higher cooling capacity)
6. Removed stock circuit for grounding grids of 3-500Zs, installed copper straps grounding all grid pins directly to ground (improved amplifier stability by removing parallel resonant circuit on grids)
7. Removed stock plate parasitic suppressor circuit, installed new plate suppressors with 100 Ohm Xicon 5W metal oxide resistor in parallel with 120 nH inductor (higher reliability, slightly improved amplifier stability)
8. Cleaned 3-500Z envelopes with alcohol to remove hand oils (prevent “hot spots” forming on glass)
9. Rewired for 120 VAC operation (since no 220 VAC currently available in 4436 EECS shack)
10. Tested amplifier on 80, 40, 20, 17, 15, and 10m bands (see results elsewhere in this document)

WARNING: Before servicing this unit you must be familiar with procedures for working with high voltage and high RF power circuits. Refer to the ARRL Handbook and the Heathkit SB-220 factory manual for more information, and consult with experienced club members. **The voltages inside this unit can easily kill you!**

Future suggested work:

1. Install a “glitch” resistor to limit high-voltage supply current surge in case of a capacitor short-circuit, internal tube arc, or other fault. The resistor should be a 25 Ohm, 25 W (minimum) vitreous enamel resistor (Ohmite 270 series or equiv.). The resistor can be mounted inside the front power supply section on 0.750 inch ceramic stand-offs mounted to the amplifier side panel, with 6-32 1/4 in machine screws, through the side panel perforations. The resistor should be wired in series with the HV power supply, from the HV capacitor bank to the plate supply, with 18 or 22 gauge insulated wire rated at no less than 5 kV.
2. Re-tune, or modify as necessary, the 10m input matching network. The amplifier currently exhibits a VSWR of 2.5 to 3 on this band, causing reduced exciter drive and thus reduced amplifier output. The input tuning network may require re-tuning, component replacement, or modification to improve the input VSWR.
3. Install a vacuum relay for high speed (QSK) amplifier transmit/receive switching. All parts should cost \$100 (new). This would make the amplifier more useful on CW and other modes requiring fast T/R switching.

Test Results

The amplifier was tested extensively after being refurbished. The following test data was taken on December 27-30, 2006. Use this data to compare future performance and assess the need for service or replacement tubes.

Test conditions:

Line voltage: 121.0 VAC (no load)
Exciter: Ten-Tec Omni VI HF transceiver
Load: Heathkit "Cantenna" dummy load

Results:

3-500Z filament voltage: 5.19 VAC

Note: This is within Eimac specifications of 5.00 ± 0.25 V, but at the high end. If the filament voltage is higher than 5.25 VAC the tube life will be significantly shortened. For line voltages below 121.0 VAC this should not be a problem with this set of tubes.

Operating points:

Parameters noted (all under load at recorded drive and output level):

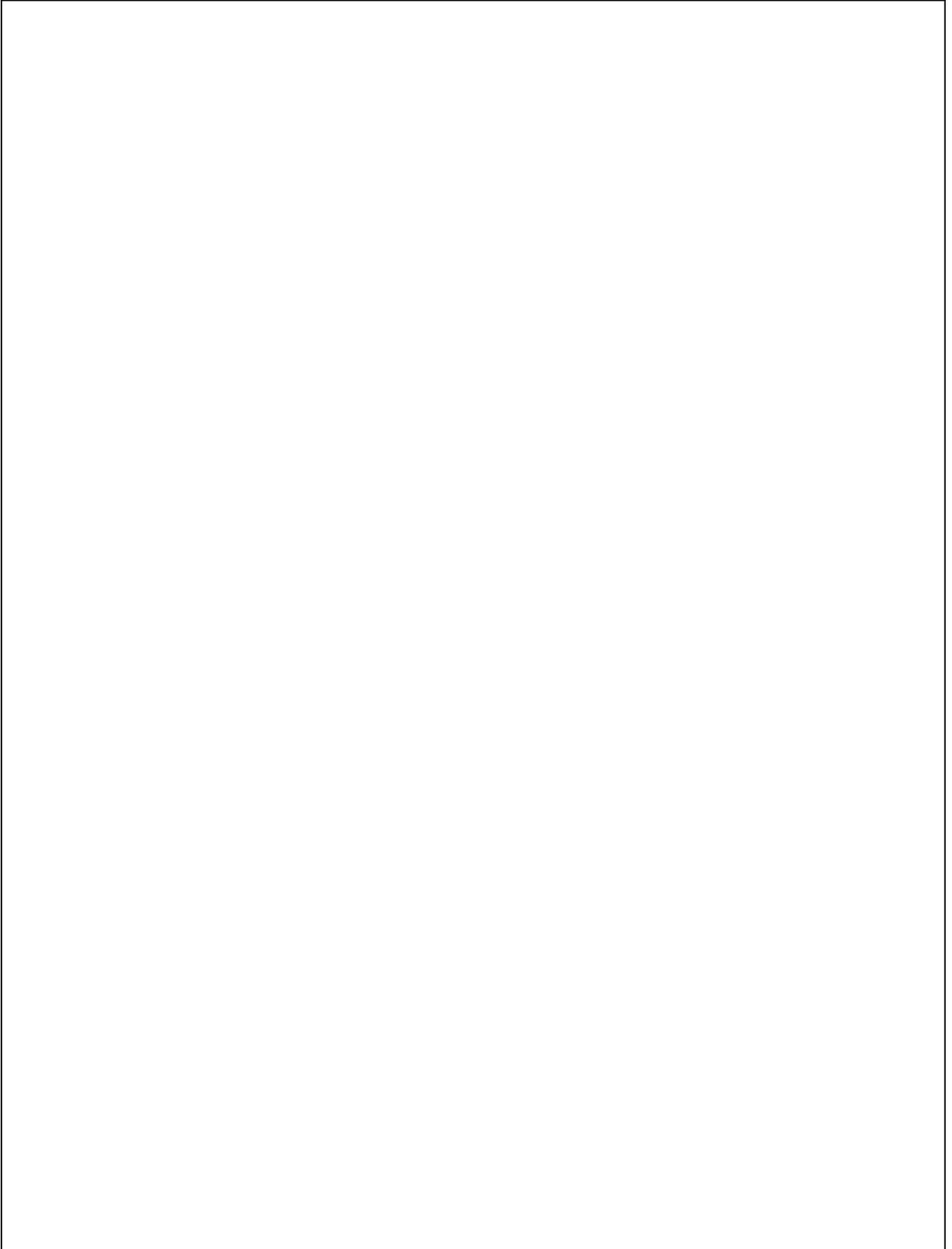
Plate voltage under load (V_p)
Plate current (I_p)
Grid current (I_g)
Output power (P_{out})
Input power (P_{in})
Efficiency (Eff.) – defined as $(P_{out} - P_{in}) / (V_p \times I_p)$
Input VSWR ($VSWR_{in}$)

Mode: CW/TUNE position

Frequency (MHz)	V_p (V) *	I_p (A)	I_g (A)	P_{out}	P_{in}	Eff. (%)	$VSWR_{in}$
3.8	2120	0.420	0.130	650	60	66.3	1.1
7.2	2120	0.420	0.110	600	50	61.8	1.1
14.2	2120	0.400	0.125	600	50	64.9	1.2
18.1	2120	0.420	0.130	600	50	61.8	1.3
21.2	2120	0.420	0.120	600	50	61.8	1.2
28.5	2120	0.450	0.140	550	50	57.7	2.5-3.0

* Measured with Fluke HV probe and digital multi-meter (the SB-220 high voltage meter reads approximately 100 V low)

Notes:

A large, empty rectangular box with a thin black border, intended for taking notes. It occupies most of the page below the 'Notes:' label.