amateur service newsletter
W6SAI

modifying the Heath SB-200 amplifier for the new 8873 zero-bias triode

Simple modification of the SB-200 linear to provide increased power dissipation, better frequency stability, and lower drive. Two designs are featured — air cooled and conduction cooled

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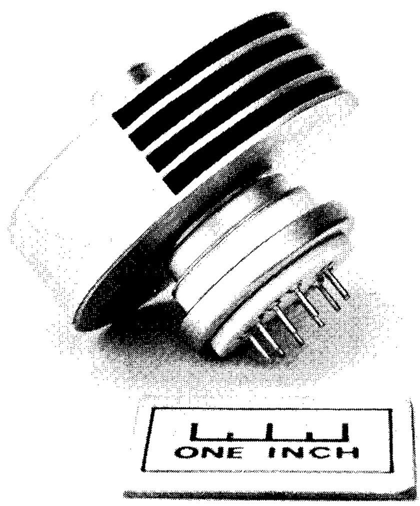
The high power capability, moderate cost and compact size of the new 8873 family of zero-bias, ceramic/metal power triodes make them well suited for new design, as well as for retrofit into popular amateur equipment that uses older tubes having restricted power capability and limited frequency range. The well-known Heath SB-200, a one-kilowatt PEP linear amplifier, is a likely candidate. This article covers the modification of this unit to use the new power tubes. The modification provides increased power dissipation,

The Eimac 8875 is a ceramic/metal zero-bias triode with a transverse cooler that provides 300 watts anode dissipation.



better high-frequency stability and lower drive requirements, and (in the case of the 8875) at a lower overall tube replacement cost then the original pair of tubes.

Based upon a study of the SB-200 circuit design, it was decided to try different modifications on two separate amplifiers. The first version uses the 8875, a high-mu power triode having 300 watts anode dissipation and capable of about 1200 watts peak input in Intermittent Voice Service (IVS).[1] The 8875 has five large, round, horizontal anode fins that may be adequately cooled with a small phono-motor fan, the type already in the Heath amplifier. This modification requires a minimum amount of disruption of the existing Heath circuitry.

The second amplifier has a more sophisticated and interesting modification: a conduction-cooled 8873 power triode (electrically equivalent to the 8875) is used with a finned heat sink for proper anode dissipation. The heat sink forms the vertical back wall of the rf enclosure.

This section discusses the first conversion, which provides full input level for the amplifier, with low intermodulation distortion and good tube life. The conduction-cooled version is described in the last part of the article.

the 8875 modification

The 8875 zero-bias power tube is shown in the photo and is capable of 1200 watts PEP input for ssb and 1000 watts when run in IVS service. The tube is about the size of a 4CX250B, has an 11-pin base and uses an inexpensive socket. Cathode and grid connections are brought out to multiple base pins, and, in addition, the grid is terminated in a low-inductance contact ring at the base of the tube which may be used for vhf operation. The anode is intended to be cooled by a horizontal air blast from a small fan. Dissipation is a function of cooling air, and a small phono-motor fan provides about 300 watts dissipation. For RTTY service, the power input level of the amplifier is dropped to about 600 watts. These levels are entirely compatible with the rating of the intermittent-duty power supply of the SB-200 amplifier.

The 8875 is mounted in a horizontal position in the approximate space previously occupied by the two glass tubes as shown in the chassis photo. The 11-pin tube socket is near the center of a small aluminum sub-chassis mounted to the rear wall of the amplifier enclosure. The existing cooling fan, mounted at the

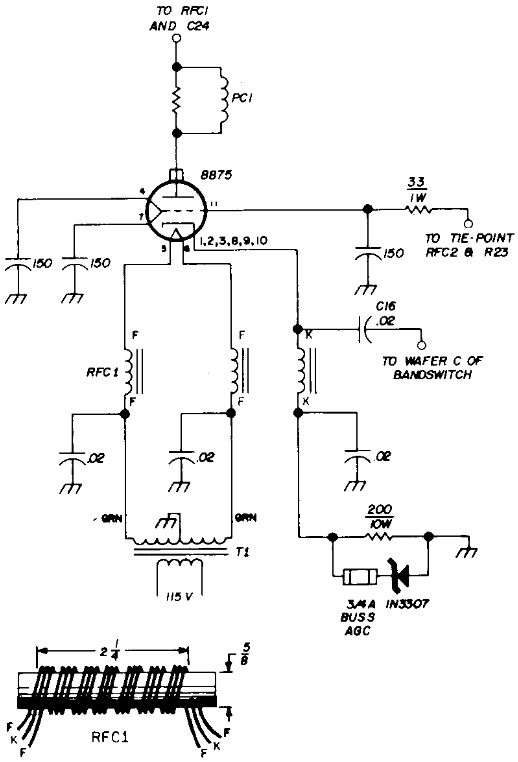


fig. 1. Revised schematic for the SB-200 shows the 8875 zero-bias triode. The 8875 requires 6.3 volts and the filament voltage in the SB-200 is on the high side because of reduced current drain. The original filament-choke windings are removed and three new windings put in their place. The filament windings are two 44" lengths of no. 20 enameled wire; the cathode winding is a 44" length of no. 26 insulated wire. Each winding has a 3" pigtail. Twenty trifilar turns are wound on the ferrite form. The ends are tied with twine and given a drop of epoxy to hold the windings in place. The socket for the 8875 is an E. F. Johnson 124-311-100. The 150-pF grid bypass capacitors are dipped mica units.

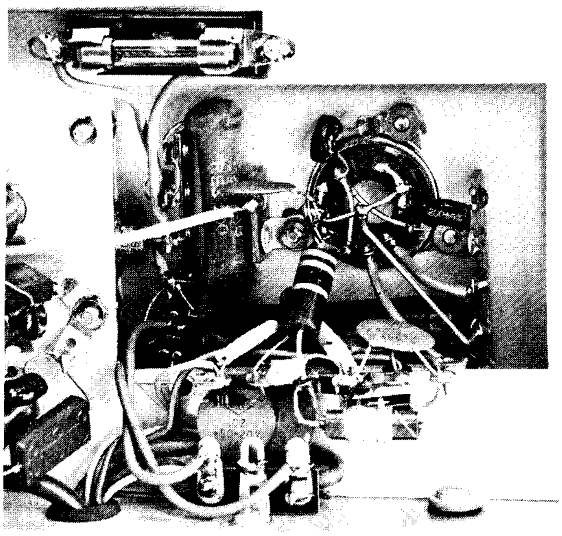
bottom of the enclosure, is moved to a new positon in respect to the anode of the 8875.

The revised circuit is shown in **fig. 1.** It uses most of the original components. A new filament choke or dropping resistor is required, as well as zener-diode bias for the 8875. All new components, with the exception of the zener fuse, are mounted within the sub-chassis, as shown in the rear-view photograph.

mechanical modifications

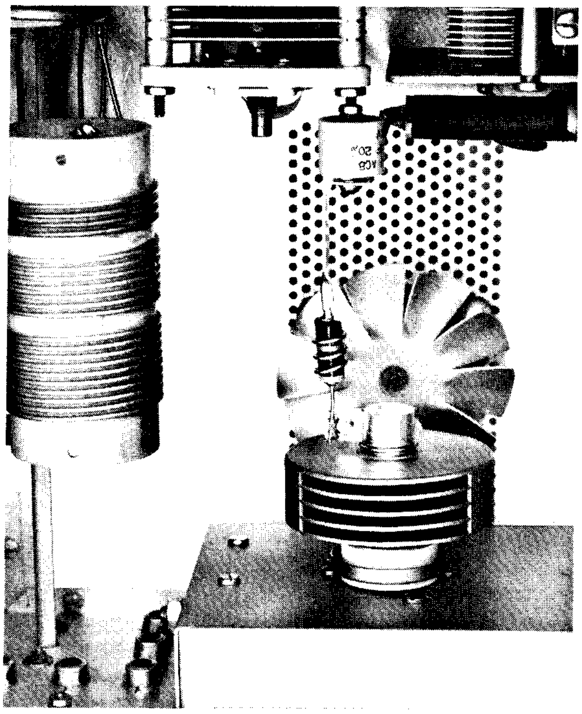
The first step is to remove the components around the existing 4-prong sockets, and then remove the sockets themselves.

Remove the filament choke from tie-point M. Unbolt tie-point AB, leaving the wiring connected. (See pictorial 11, page 39 of the Heath Instruction Manual. Original components are identified by their Heath nomenclature.) The next step is to cut out a rectangular hole on the rear wall of the enclosure as shown in the rear-view photo, with the dimensions



The rear panel of the SB-200 is cut out to allow access to the underside of the new sub-chassis. Untouched cathode coils are to left of the cutout. The zener fuse is at top of cutout with 200-ohm cathode resistor and zener diode mounted in sub-chassis. In this installation an extra cathode choke was used with the original SB-200 filament choke. The cathode choke has 15 μH inductance and 1000 mA current rating (J. W. Miller 4624).

In the modified Heath SB-200 the 8875 is mounted horizontally in the space formerly occupied by the two glass tubes. Major plate circuit components remain unchanged.



shown in **fig. 2.** The new sub-chassis for the 8875 is placed over this hole. The sub-chassis is a 4 x 5 x 2-inch Bud AC-1404 chassis cut down to 1-¼" height and held in place with spade lugs and bolts. The tube socket is placed on the sub-chassis as shown in **fig. 2.**

The new sub-chassis interferes with various bolts holding the rf enclosure to the main chassis deck along the bottom rear edge, and it is necessary to provide clearance for these bolts. Proper clearance is provided by noting position of the bolts and drilling ¼-inch clearance holes in the sub-chassis at the points of interference.

Once the sub-chassis is in position, the tube is placed in the socket and the phono fan moved until the blades are positioned beneath the anode of the tube as shown in **fig. 3.**

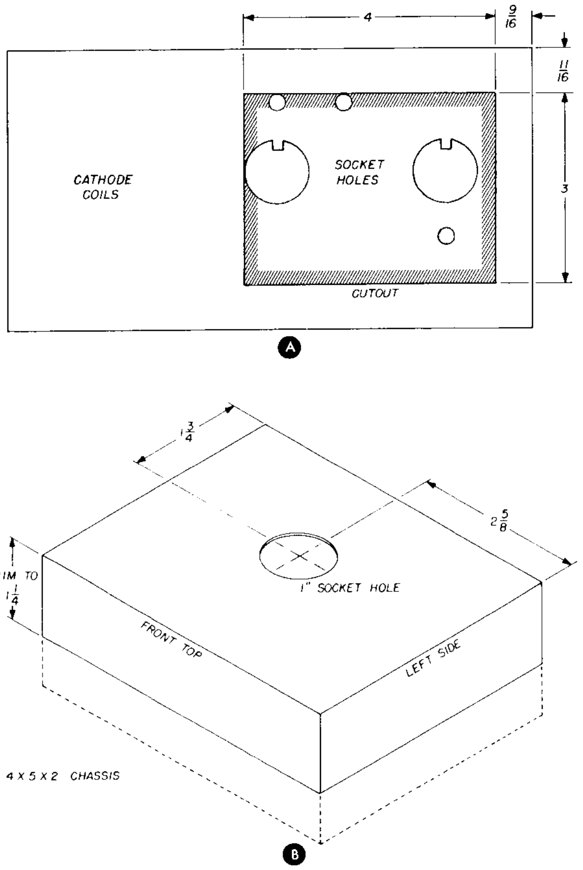


fig. 2. SB-200 chassis modifications to accomodate the 8875. The enclosure cutout for the sub-chassis is shown in A. The modified sub-chassis for the 8875 socket is shown in B.

electrical modifications

The portion of the original schematic of the SB-200 that is revised is shown in **fig. 1.** The 1N3307 8.2-volt zener diode is bolted firmly to the wall of the sub-chassis, using a thin coating of *Wakefield Thermal Compound* smeared on the zener stud to allow a good thermal bond. The new component layout in the sub-chassis is shown in the rear-view photograph.

Using the new tube, the existing filament voltage of the SB-200 is too high, and it is necessary to drop it slightly to avoid over-volting the tube filament; a 0.3-volt drop is necessary. This may be readily achieved by placing a 0.1-ohm wirewound resistor in series with one filament lead, or the filament choke may be rewound with the proper wire length and size to develop the required voltage drop. Since a cathode rf choke is required, the builder has the option of rewinding the present filament choke and adding a cathode winding as shown in **fig. 1** or using the existing choke and adding a cathode rf choke and filament dropping resistor. The latter was done for the first tests, and a new trifilar rf choke was substituted at a later date.

amplifier testing

When the modification is complete, all wiring should be checked and the resistance to ground from the anode clip should be checked. As in the original amplifier, before modification, the resistance should be about 180,000 ohms (the resistance of the filter bleeder resistor, $R_5 - R_{11}$). The amplifier should be connected to the exciter and to a dummy load. Before the amplifier is turned on, the exciter is tuned up, feeding through the unenergized antenna relay of the amplifier. The amplifier is now turned on, and the panel meter should read about +2400 volts in the HV position. Amplifier plate current is zero because of the cut-off bias voltage.

The amplifier controls are set as des-

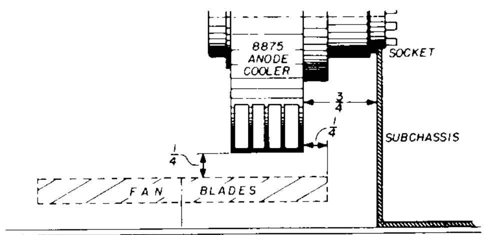
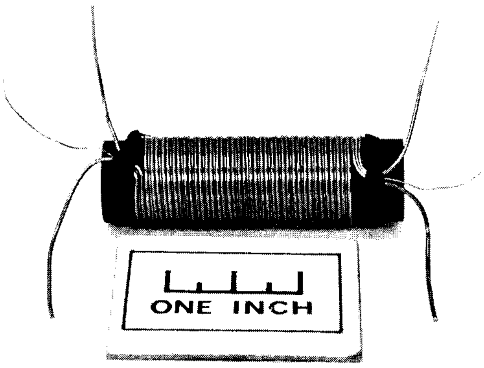


fig. 3. Phono-motor fan installation for the 8875. The motor must be moved so the shaft is in line with the center of the anode, and the tip of the fan blade clears the bottom of the tube by 1/4 inch. The blade should also clear the edge of the anode by 1/4 inch.

cribed in the *Operating Procedure* section of the Heath Manual (page 47), and the amplifier is again turned on. With no driver output, the meter of the amplifier should indicate an idling plate current of about 20 milliamperes. A ninety-second cathode warm up time should be observed before excitation is applied to the



New trifilar filament and cathode choke for the modified SB-200 uses ferrite rod from original unit. Winding details are shown in fig. 1.

8875. The drive level of the exciter is advanced until the plate current rises to about 200 milliamperes. Tuning and load controls are adjusted for maximum power output (minimum plate current) on the amplifier meter. Grid current should be about one division on the meter (25 milliamperes, or less). **Caution:** *The 8875 is easy to drive; watch out for excessive grid current.*

The amplifier may now be loaded for a maximum plate current of 500 milliamperes, using carrier injection from the exciter. Maximum grid current is 45 milliamperes. This corresponds to a drive level of 55 watts or less. Loading should be done quickly so as to not run excessive IVS plate current for more than 30 seconds or so.

When proper loading with carrier injection is achieved you will find that maximum power output occurs at this point along with the recommended values of plate and grid current. At maximum input the power output (measured with an accurate wattmeter) is between 520 watts (10 meters) and 630 watts (at the lower frequencies). Power gain is about 10 decibels. Under voice conditions, with no speech processing, voice peaks will run about 200 milliamperes on the meter.

Thanks to Merle Parten, K6DC, and Dick Rasor, WA6NXB, for their help and assistance in modifying the amplifier and making measurements on the completed version.

conduction-cooled linear

Modern power tubes such as the 8873-family have the capability of developing anode power dissipation densities (watts per square centimeter) comparable to the power densities in many jet and rocket engines. For this reason, effective cooling techniques are essential for long life and high tube reliability.

Conduction cooling is an efficient system of heat elimination, making use of the *heat source* (power tube or transistor), a heat transmission path (*thermal link*) and a *heat sink,* wherein the heat is removed. Many amateurs have seen transistors with tiny heat sinks on them; far fewer amateurs have observed heat-sink systems capable of dissipating several kilowatts of power. Such large systems exist, and the general design (suitably scaled down) may be adapted for use at amateur power levels. Although common in commercial and military gear, the heat-sink conduction-cooled system is just beginning to appear in amateur equipment (i. e., the Signal-One transceiver).

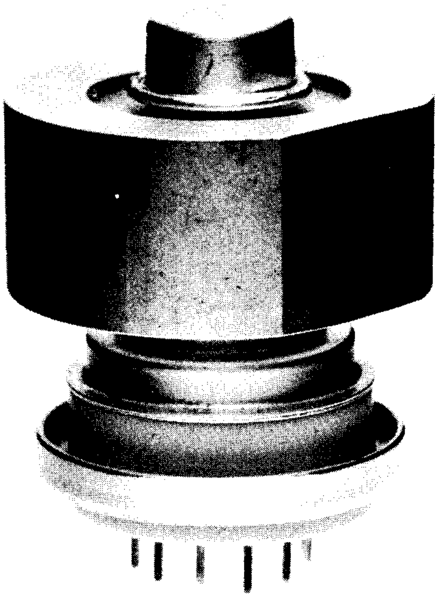
In the case of a power tube whose anode operates at a high voltage potential, the thermal link must have the dual properties of a thermal conductor and an electric insulator. One of the most practical materials for this task is *Beryllium Oxide* (BeO), an insulative ceramic (refractory) material which has the thermal conductive properties of aluminum.

The 8873 zero-bias power triode makes use of a BeO thermal link and external heat sink. The link is detachable, providing mounting flexibility and reduced tube replacement cost. However, since two thermal interfaces occur with the detachable link (tube anode to link and link to heat sink), attention must be paid to ensure low thermal resistance at these two interfaces if optimum cooling performance is to be achieved.

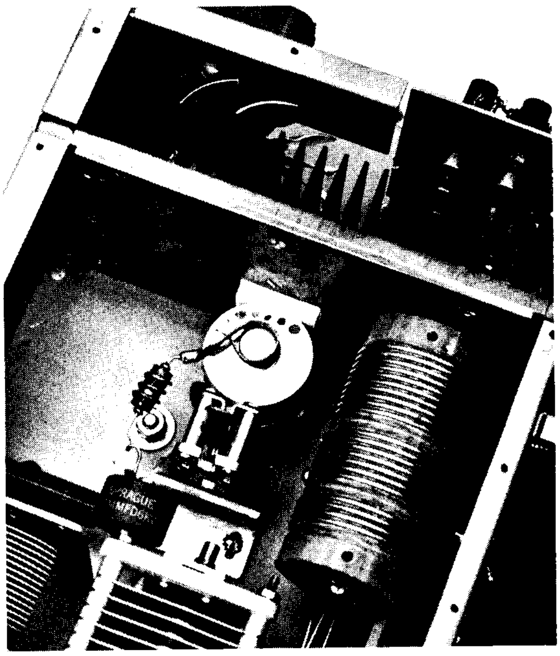
The heat sink, receiving heat through the thermal link from the tube anode, emits energy in the form of radiant heat. The quantity of heat radiated depends upon the absolute temperature of the sink relative to the surrounding environment and the nature of its surface. A heat sink operating at an elevated temperature compared to its environment will transfer heat to the environment by radiation, convection and conduction, as is done in this case.

The added output capacitance of the tube supplied by the thermal link and heat sink is typically 6 to 10 pF, and this must be taken into account when vhf tank circuits are concerned.

The heat sink used with power tubes may be liquid or air cooled. In this case two or three hundred watts of anode dissipation are required so air cooling is feasible.



The 8873 conduction-cooled zero-bias triode.



Conduction-cooled 8873 zero-bias triode mounted in the Heath SB-200 linear. The 8873 is held in place with a toggle clamp that presses the anode of the tube against a beryllium-oxide thermal link and finned heat sink. The flat surface of the heat sink is covered with 1/8-inch copper sheet to distribute anode heat evenly. Under normal voice operation heat-sink dissipation provides sufficient cooling. For cw or long-winded voice operation a thermal switch turns on a small phono-motor fan to hold the temperature of the heat sink at a conservative level. When heat-sink temperature drops to normal value, the fan is automatically switched off.

the 8873

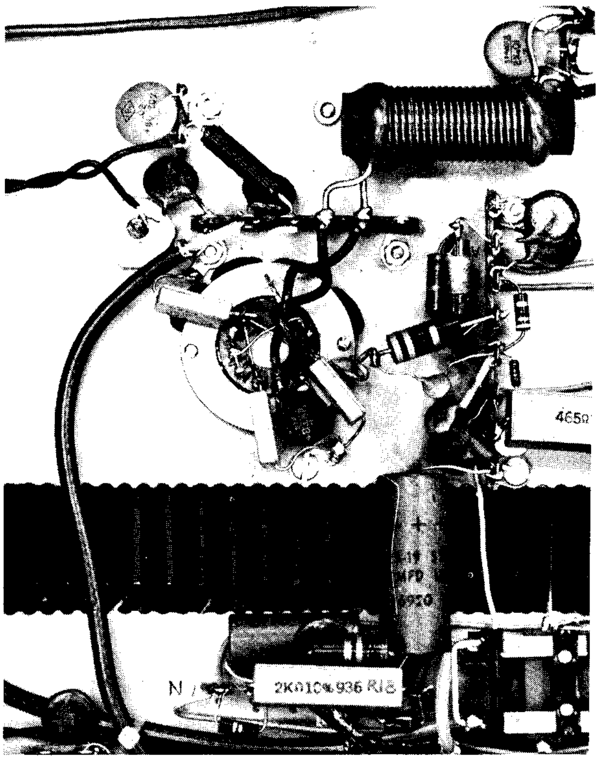
The 8873, like the 8875, is a ceramic/metal, zero-bias triode intended for hf and vhf service up to 450 MHz or so. No air cooling of the base is required if the socket is mounted on a chassis which has sufficiently low thermal resistance to drain the filament heat away from the stem of the tube.

The 8873 seemed a natural for retrofit in an existing Heath SB-200 amplifier. It was planned that the cabinet and power supply of the SB-200 could be used as a test bed for future experiments (such as a 50 MHz or 144 MHz amplifier) so a new, two-piece aluminum chassis was made. The power supply was rebuilt on one chassis and the amplifier section on another. Both units were then bolted together to resemble the original Heath chassis and shields. An amateur intending to modify his own SB-200 to this design probably would use the Heath metal work as-is.

heatsinking the SB-200 chassis

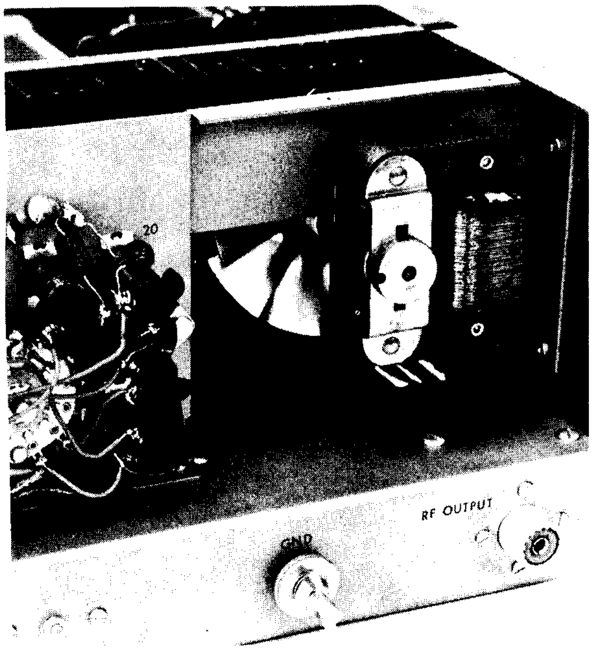
The 8873 anode is heat sunk to a finned radiator mounted at the rear of the amplifier enclosure. Generally speaking, the modification consists of removing the present tubes, sockets and auxiliary components and reworking the circuit electrically as described in the 8875 modification. Views of the heat sink installation are shown in the photographs. The heat sink measures 7-3/4 x 4-1/4 inches and is mounted to the chassis and side walls about 8-3/4 inches behind the front wall of the enclosure. The 8873 socket mounts in the center of the enclosure, with the center of the socket about 15/16-inch from the smooth surface of the heat sink.

Anode heat flows from the 8873, through a BeO insulating block into the heat sink. Good bonding is essential between these three components in order to hold anode core and seal temperatures below the maximum permitted rating of 250°C. To hold the components firmly together, a DE-STA-CO toggle clamp is mounted in front of the tube. A small ½-inch ceramic insulator is substituted for the rubber nose of the clamp, which presses against the tube and heat sink. While the clamping action takes place, the tube and socket should be free to move. Accordingly, the socket is mounted in a clamp ring so that a slight amount of rotational and lateral movement can be accomplished. The rotational movement is required in order to align the flat surfaces of the tube, thermal link and heat sink. The socket is then tightened in position after alignment and clamping takes place.



Bottom view of amplifier chassis shows sub-mounted tube socket. Chassis bolt holes are slotted so tube and socket may be moved slightly so the anode is properly seated against the heat sink. The rear of the amplifier chassis has been cut away below the heat sink so cooling air may pass through the fins. Filament choke is at upper right with zener diode mounted on chassis at upper left.

The heat sink provides about 160 watts of continuous anode dissipation when cooled by normal currents of 20°C air (room temperature). It is possible to raise the dissipation of the sink to about 200 continuous watts by passing cooling air across it from the small phono-motor fan which was a part of the original SB-200 assembly. The fan was included in this design, along with a thermal switch.



Rear view of conduction-cooled amplifier shows cooling fan and cathode tuned circuits. Chassis beneath the heat sink has been cut away for proper flow of cooling air.

When the temperature of the heat sink approaches a value that indicates high anode temperature, the fan is automatically switched on, increasing the capacity of the sink and protecting it from long-winded rag chewers and marathon talkers.

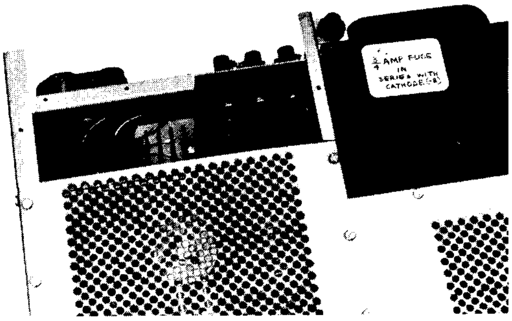
To determine the capacity of the heat sink system, temperature runs were made on the sink and tube anode, with various values of anode dissipation. Heat-sink and anode temperature were measured with temperature sensitive paint, and the thermal switch was moved about on the sink until it switched on when anode temperature reached about 180° C, well below the upper design limit of the tube.

To hold tube base temperature to a safe level, slots were cut in the chassis around the tube socket to allow cooling air from beneath the chassis to flow up and around the tube base (see under-chassis photo).

amplifier operation

Tuning and loading of the amplifier is normal, and follows the procedure outlined in the 8875 description. Under most operating conditions, the heat-sink temperature does not rise to the point at which the cooling fan is actuated, and amplifier operation is completely noiseless, a welcome "sound" these days!

While this unit is considered to be experimental, it points the way to the amplifier design of tomorrow: heat-sunk, noiseless, compact and highly efficient – quite a far cry from the old days of rack mounted gear, heavy, buzzing power supplies and black-crackle panels. How time flies!



Conduction-cooled amplifier with top shield in place. Shield has been trimmed at rear to allow air to flow over heat sink.

Again, thanks to K6DC and WA6NXB for their assistance in this experimental project.

reference

1. William I. Orr, W6SAI, "Intermittent Voice Operation of Power Tubes," *ham radio*, this issue.

ham radio