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Tube Envelope Temperature

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OPERATING TEMPERATURE of tube envelopes becomes increasingly important as the size of electronic equipment is reduced. If the same amount of power is to be dissipated within two enclosures one of which is much smaller than the other, the temperature of the smaller enclosure will rise to much higher values than that of the larger. This fact is borne out in Table I, which indicates both areas and maximum dissipations for the bantam or T9 tube, the miniature or T5½ tube and subminiature or T3 tube. It will be noted that as the sizes decrease, the value of watts per square inch is increased and the maximum bulb temperature is increased correspondingly. The life of a vacuum tube is materially affected by the operating temperature of its bulb, as well as its other parts.

TABLE I—Bulb Temperature at Sea Level

	T9	T5½	T3
Bulb Area (Sq In.)	10.5	4.1	1.7
Max. Watts Dissipation	18.7	16.8	7.8
Watts per Square Inch	1.78	4.1	4.6
Max. Bulb Temp deg C Ambient 23C	160	255	280

There are some absolute limits on the permissible glass temperature, one being the softening point of the glass and another the point at which appreciable conductivity occurs—called electrolysis. Below these limits there is an indefinite region in which varying kinds and degrees of trouble are encountered, especially owing to evolution of gas from the bulb, itself the getter and other tube parts. The temperature of concern is that at the hottest spot on the envelope, which usually occurs midway between the top and bottom micas. The location can be readily found by the use of temperature sensitive lacquers marketed by Tempil Corporation, 11 West 25th Street, New York City.

During manufacture, while the vacuum tube is on the production pumping set-up, the envelope and the metal parts within the tube structure are heated to much higher temperatures than those to which they would normally be subjected during operation in order that all of the absorbed and adsorbed gases may be removed. If, however, during operation, the operating temperature of the envelope or the parts themselves exceeds the temperatures reached while the tubes were being pumped during production, it is likely that varying amounts of gases will adversely affect tube life.

Normally, the function of the getter that produces the silver-like deposit or the black deposit on some of the newer tubes is to provide a means for removing any gases that may subsequently be set free during the operation of the tube. There is a limited amount of gas that this getter material can safely pick up. Amounts beyond this will result in the tube's gas content being materially increased. In addition, if the glass bulb should be heated sufficiently the getter patch may be caused to migrate or leave the bulb.

TABLE II—Bulb Temperatures 23° C Ambient at Sea Level

		Percent Maximum Plate Dissipation				
Type	Bulb	20	40	60	80	100
12AU7	T6½	77C	100C	118C	133C	146C
6C4	T5½	64	82	98	113	125
6AH6	T5½	88	103	116	126	132
5U4G	ST16	105	116	127	138	149
5687	T6½	123	140	155	155	183

It may redeposit itself on some cooler part of the tube so that a considerable amount of gas trapped by the getter will now be released and may not recombine when the getter condenses on the cooler portions of the tube. In this instance, then, the gas content would also be materially increased. Should the getter condense on the mica supports of the tube there is a possibility that leakage between elements supported in the mica may be increased. This leakage may affect performance materially.

As seen from Table I, a tendency to decrease the size of electronic gear aggravates the bulb-temperature condition. Tube life, in general, can be extended by maintaining low temperatures for the glass envelope. This is especially important in high-power output tubes because of their higher plate and cathode dissipations. The temperature rise in the envelope may be limited by: reduction of total tube dissipation; provision for improved ventilation; maintenance of low ambient temperatures.

TABLE III—Sea Level Bulb Temperatures vs Dissipations and Ambient Temperature Variations

	Watts per Sq In.				
Ambient	1	2	3	4	5
	Bulb Temp deg C at Hottest Spot				
23C	100	170	230	280	310
160	220	260	300	340	370
250	310	350	390	420	450

In general, the envelope temperature of small receiving-type power tubes should be kept below 175 deg centigrade for increased reliability. The chief effect of high temperature on vacuum tubes is not a sudden change in operating characteristics but a gradual deterioration of characteristics. Table II indicates the operating bulb temperatures for five types of tubes, having various sized envelopes for plate dissipations ranging from 20 per-

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cent up to maximum rated dissipations. This gives an idea of the extent to which it is possible to reduce bulb temperatures by decreasing the total tube plate dissipation.

The ultimate bulb temperature depends not only upon the dissipation within the tube itself but also upon the temperature of the surrounding air immediately adjacent to the tube envelope. Table III shows how these ambient temperatures affect the bulb temperature for various watts per square inch dissipation. From these data it is apparent that precautions must be taken to keep the ventilation around the tubes such that the temperature will be as low as possible.

The importance of bulb temperatures on tube life can be noted in recent information published by various tube manufacturers showing the life which may be expected for subminiature tubes. Most of these tubes are rated for maximum bulb temperatures of 200 deg with a few having a rating of 250 deg C. A reduction of bulb temperature on the order of 20 percent when operating in the region of 200 deg C bulb temperatures will result in a substantial increase in the life expectancy of the tubes. The cooling of the tube envelope is the most important consideration in mounting the tube.

A loose-fitting shield such as is commonly employed with miniature tubes may increase the temperature appreciably. The situation arises because the shield is not tight fitting but instead provides a blanket of hot air around the tube. Thus the shield does not provide a good thermal contact with bulb of the tube or to the chassis and cannot effectively cool the bulb.

If shields are employed, and they are tight fitting and can be fastened directly to the chassis, a considerable amount of heat can usually be removed in this manner. To obtain maximum heat radiation, the shield should not be plated and should not be polished.

So far, sea-level altitudes have been assumed. Many tubes operate at high altitudes some or all of the time. This environment aggravates the cooling problem still more since the density of the air decreases with altitude. The decreased effective cooling of a tube at higher altitudes requires that the total tube dissipation be derated in order not to exceed critical bulb temperatures. This derating depends upon the altitude and may amount to as much as 40 or 50 percent.

To obtain maximum reliability from vacuum tubes and equipment, it is important that pains be taken to keep the operating temperature of the bulb at its hottest spot within the limit specified by data sheets.

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